# H I L G A R D I A

*A Journal of Agricultural Science Published by the California Agricultural Experiment Station*

VOL. 13 FEBRUARY, 1940 No. 2

# FACTORS AFFECTING THE TOTAL SOLUBLE SOLIDS, REDUCING SUGARS, AND SUCROSE IN WATERMELONS[1]

D. R. PORTER,[2] C. S. BISSON,[3] AND H. W. ALLINGER[4]

## INTRODUCTION

EDIBLE QUALITY in watermelons is determined by several contributing chemical and physical factors. To be of high quality the flesh must be deep red in color, of crisp texture, and high in sugar content. Our American varieties manifest marked variation of these characters and foreign varieties are even more variable. While the relative intensity of these characters may vary slightly from season to season in a given locality, such variation is much less pronounced than the consistent differences among varieties. Many varieties have been grown at Davis annually since 1930, and yearly differences in these characters, while slight, could easily be due to a slight difference in genetic constitution of variety. For instance, Striped Klondike No. 11 has consistently contained more sugar than other varieties tested. Again, Tom Watson and Kleckley Sweet, annually have manifested pale-red rather than deep-red color. Thus, year after year, the varieties maintain a certain identity.

It is not inferred here that these characters might not be influenced by environmental conditions, extent of foliage development, or total fruit yield expressed in pounds per plant. Varieties do vary in the amount of leaf surface and relative size of leaves. Certain small-fruited varieties characteristically produce six to ten fruits, while others, such as Tom Watson, rarely produce more than three fruits per plant. Data

[1] Received for publication December 20, 1938.

[2] Associate Professor of Truck Crops and Associate Olericulturist in the Experiment Station. Resigned January 1, 1939.

[3] Professor of Chemistry and Chemist in the Experiment Station.

[4] Analyst, Division of Chemistry.

are not available on plant yield as related to these phases; but, in this connection, data previously published by the senior author (*4*)[5] are significant. The summary of the paper cited states that "inbreeding tends to isolate strains producing more or fewer fruits per plant than commercial stock, but the variation in average fruit weight often compensates for reduction in number of fruits per plant." The authors have no careful experimental data on the effect of plant yield on sugar content, but observations at Davis have indicated that among the varieties tested, there appeared to be a positive correlation of small-fruited types with increased prolificacy.

The relation of environment to total soluble solids and sugars is discussed in detail elsewhere in this paper. At this point, however, the reader is referred to another paper (*6*) in which it is shown that of many strains tested in duplicate at Davis and at the Meloland station near El Centro in the Imperial Valley, the total soluble solids content for a given strain was nearly identical at these two locations. Furthermore, the Leesburg variety when grown at Davis and at Modesto was identical in the content of total soluble solids even though grown on silt loam soil at Davis and on sand at Modesto.

The studies reported herein were initiated at Davis, California, in 1933. They deal with total soluble solids and sugars found in the important varieties of watermelons now grown in the United States. They also include discussion of certain varieties which have resulted from hybridization of American and foreign varieties. They indicate that the factors for sugar content are heritable, but that certain environmental conditions may affect both total soluble solids and sugars of genetically pure strains.

## REVIEW OF LITERATURE

Only meager information is available on the relative sugar content of American varieties (*7, 9*), and the variations have not generally been expressed numerically. The relatively low sugar content of Pride of Muscatine, a wilt-resistant variety isolated by Porter and Melhus (*8*), has definitely contributed to its unpopularity with growers. As a result, the Iowa Agricultural Experiment Station has recently released Improved Kleckley Sweet No. 6 which, as shown in this paper, is much superior to the Pride of Muscatine in sugar content. Furthermore, the sugar content of Improved Kleckley Sweet No. 6 is equal to that of Kleckley Sweet, from which it was isolated, and occasionally it averages slightly higher than the parent variety. This inferiority of Pride of

[5] Italic numbers in parentheses refer to "Literature Cited," at the end of this paper.

Muscatine has also been recognized in Florida, and Walker (*10*) found it necessary to develop the wilt-resistant variety Leesburg, which is also a selection from Kleckley Sweet. At the California station, Pride of Muscatine, Iowa Belle, and Iowa King have been crossed with Klondike to secure wilt-resistant Klondike strains, but resistant segregates involving Pride of Muscatine have been so consistently low in sugar content that these hybrids have been discarded in favor of those involving Iowa Belle (*6*), despite the unattractive skin color of this parent. This is not a condemnation of Pride of Muscatine; in fact this variety represents the first successful attempt to secure resistant strains without resorting to hybridization with the resistant but inedible citron types, and other breeders (*10, 11*) have adopted similar breeding technique.

An important phase of the watermelon-breeding program in California has centered around the development of wilt-resistant types of equal quality with Klondike. Obviously, high sugar content is much desired in a new variety.

Preliminary studies were initiated in 1933 and briefly reported (*7*). At that time it was shown that the sugar content varied among varieties; that, in general, there was a distinct correlation between total soluble solids and sugar content; and that, as the fruit of the Klondike variety matured, a portion of the reducing sugars probably changed to sucrose. The present paper represents a more detailed study of varietal differences, a study of the rate of development of sugar types during maturity, a similar study of sugar changes in stored and overmature fruits, the possible effects of varied environmental conditions affecting sugar development, and the relation of inbreeding to sugar content.

## CULTURE

All fruits used in the present study were grown at Davis. Seed was planted in April, May, June, or July and the crops matured from early August to early December. All varieties received practically identical care incident to cultivation, irrigation, and insect control. The plants were spaced 9 by 6 feet and only one plant was left in a hill.

## METHODS OF ANALYSIS

*Determination of Total Soluble Solids.*—By means of the Brix hydrometer it was possible to obtain the approximate percentage of total soluble solids in the extracted juice. This method, although reasonably accurate, proved to be too slow as it required the removal of at least 50 cc of juice from each fruit. Determination of the index of refraction of juices, using

an Abbé refractometer,[6] gave values which were interpolated in terms of total soluble solids (primarily sugars) and these results were found, by a series of experiments, to be in good agreement with the percentage of total soluble solids (primarily sugars) as obtained with the Brix hydrometer; but this method also was too slow as samples of juice had to be collected in vials in the field and brought to the laboratory for the determinations. Finally a small hand refractometer was used; its scale is calibrated directly in the per cent soluble solids. Admittedly it is somewhat less accurate than either the Abbé refractometer or Brix hydrometer, but it has the advantage of adaptability to field conditions and proved to be more than five times as rapid as the Abbé. The scale readings may be read to $\pm$ 0.2 per cent. Only two or three drops of solution are needed for a determination.

The method of securing juice varied with the quantity needed, but all fruits were cut parallel with the polar diameter and juice taken from the heart flesh, unless otherwise stated. For the Brix tests, approximately 500 grams of edible tissue were crushed and filtered through four layers of cheesecloth, then 50 cc of the juice placed in a graduated cylinder at room temperature, and readings recorded. For the Abbé tests, a 1-inch cube of flesh was squeezed in the hand and the juice collected in 10-cc vials which were brought to the laboratory for the determinations. For the hand refractometer tests, a much more rapid method of sampling was used. It was found that sufficient juice would adhere to a small glass rod, when forced into the center of the flesh and withdrawn, for a single determination. Readings were made immediately in the field; this saved both time and labor, and prevented changes in composition of the juice. Unless otherwise indicated, the hand refractometer was used for the determination of the percentage of total soluble solids.

The amount of juice used for hand-refractometric measurement was a very small fraction of the total amount in the fruits. It was therefore necessary to test the accuracy of this method of sampling. Observations on the composition of a single watermelon by Tucker (*9*) show that there are variations in the percentage of total soluble solids in the juice obtained from different regions of the watermelon. Since it is obvious that the number of samplings by his method would have been excessively great in order to obtain the requisite data for this investigation, a shorter procedure was adopted and this method was tested for reliability as follows.

[6] This instrument gives the refractive index of the juice samples, and from the factor thus secured the total per cent soluble solids is obtained by interpolation, using table 5 from Browne's *Handbook of Sugar Analysis* (*2*).

Samples of juice were secured from seven arbitrarily chosen regions of a fruit as indicated in figure 1. The index of refraction was first determined by the hand refractometer on samples secured from the center portion of the fruit. Additional readings were then obtained immediately on the juice from the six remaining regions of the fruit. Three or more fruits of each variety were sampled in this manner. The values obtained from these seven samplings were averaged for each fruit. The

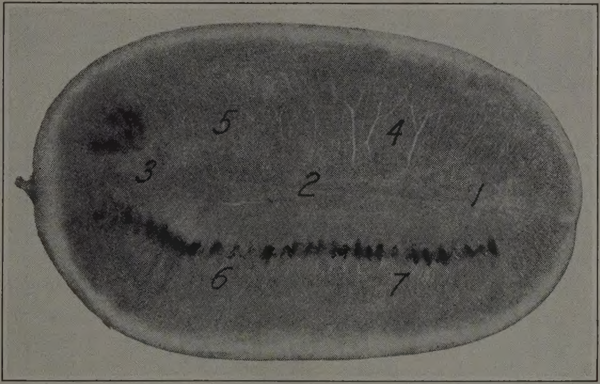


**Fig. 1.—Longitudinal section of a typical Klondike fruit, indicating the seven places where determinations of total soluble solids were made to provide the data for table 1.**

average values for all the fruits of a single variety or strain were then averaged and these results are recorded in columns 3 and 4 of table 1. It is evident from these data that when readings of three or more fruits are averaged the greatest difference found in 14 comparisons was only 0.3 per cent. It is therefore apparent that center readings with the hand refractometer are sufficiently accurate for determining total soluble solids in mature fruits.

As a further necessary check, a measurement was made from juice secured from the center of a mature fruit. Immediately afterward the edible flesh of the same half of the fruit, located almost entirely within the seed zone, was removed, crushed, and the juice strained through four layers of cheesecloth; a reading was then made with a few drops of the composite juice sample. A portion of this composite sample was also used for determination of sugars by chemical methods. A total of 280 fruits were examined, representing 14 varieties and strains. It is unnecessary to tabulate complete data for all of these fruits. The average readings for each of the 14 varieties and strains appear in columns 7

TABLE 1

COMPARATIVE HAND-REFRACTOMETER DETERMINATIONS OF TOTAL SOLUBLE SOLIDS IN MATURE WATERMELONS FOR TESTING ACCURACY OF THE METHOD OF SAMPLING

| Strain or variety | Number of fruits | Total soluble solids, per cent | | Strain or variety | Number of fruits | Total soluble solids, per cent | |
|---|---|---|---|---|---|---|---|
| | | Average of center sampling | Average of seven regions | | | Average of center sampling | Composite sample of extracted juice |
| *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| R3 | 5 | 12.1 | 11.9 | Klondike R7 | 20 | 11.8 | 11.8 |
| R4 | 9 | 11.8 | 11.7 | California Klondike No. 3 | 20 | 11.6 | 11.7 |
| R6 | 6 | 11.0 | 10.7 | Striped Klondike No. 11 | 20 | 12.7 | 12.5 |
| R7 | 4 | 12.4 | 12.2 | Iowa Belle | 20 | 10.9 | 10.6 |
| R16 | 5 | 11.5 | 11.4 | Stone Mountain | 20 | 10.9 | 10.8 |
| R7-4-12 | 3 | 12.8 | 12.8 | Tom Watson | 20 | 10.4 | 10.5 |
| R7-4-7 | 4 | 13.8 | 13.5 | R7-9-4 | 20 | 11.6 | 11.9 |
| R17-3-6 | 6 | 12.8 | 12.6 | R7-7-1 | 20 | 12.6 | 12.2 |
| R19-7-10 | 3 | 12.0 | 12.0 | R7-6-2 | 20 | 12.0 | 12.2 |
| California Klondike No. 3 | 10 | 11.9 | 11.6 | R7-4-16 | 20 | 12.0 | 11.6 |
| Striped Klondike No. 11 | 10 | 13.6 | 13.5 | R8 | 20 | 11.5 | 11.8 |
| Iowa Belle | 10 | 11.1 | 11.0 | R16-3-9 | 20 | 12.3 | 12.4 |
| Stone Mountain | 10 | 11.2 | 10.9 | R17-1-9 | 20 | 12.4 | 12.0 |
| Tom Watson | 10 | 10.6 | 10.4 | R19-7-10 | 20 | 11.4 | 11.6 |

and 8 of table 1. These data show that the actual difference by the two methods was not more than 0.4 per cent, which is approximately the same as the deviations for the average readings. The "center" method of sampling was therefore proved to be a sufficiently accurate method for sampling mature fruits.

With immature fruits, however, the center readings were usually higher than the composite readings and any determinations discussed herein for immature fruits are based on juices prepared by the composite method, and not on the center method of sampling.

Several seedsmen, growers, and shippers now use the hand refractometer to advantage. Admittedly, variations in the temperature influence the refractive index, but the maximum effect on the scale readings by variations in temperature during the measurements was less than the sampling error.

*Determinations of Sugars in Juice.*—Each sample for chemical analysis consisted of one liter of expressed juice. Usually, 100 cc was secured from each of 10 fruits. If less than 10 fruits were used, the volume taken from each was identical. Such juice was collected in the afternoon, placed in liter flasks, covered with a thin layer of toluene, stored overnight at 3.5°–5° C, and analyzed the following day. The method of sampling was identical with that used in securing composite samples for hand-refractometer tests. Sugars were determined by the Quisumbing-Thomas method (*1*). The results of these determinations are recorded in the tables under total sugars, reducing sugars, and sucrose. A few determinations of levulose and dextrose were made by the iodine oxidation method of Lothrop and Holmes (*3*). These results are shown in table 12.

## CORRELATION OF TOTAL SOLUBLE SOLIDS AND TOTAL SUGARS

If the readings obtained by use of the hand refractometer are to express with reasonable accuracy the relative sugar content, then the changes in the refractometric readings should follow primarily changes in the sugar content. To determine this dependence, extensive comparisons were made not only with individual fruits but with large numbers of fruits of different varieties. The results of a preliminary test conducted in 1933 with fruits of the Klondike variety are summarized in table 2. The ratios of total sugars to total soluble solids varied from 0.685 to 0.891, but these fruits had not been tagged at anthesis and some were slightly immature when harvested. As indicated earlier, the center readings are accurate only for mature fruit.

TABLE 2
RELATION OF TOTAL SOLUBLE SOLIDS AND TOTAL SUGARS IN INDIVIDUAL FRUITS OF COMMERCIAL KLONDIKE WATERMELONS AT DAVIS, 1933*

| Fruit number | Total soluble solids per cent | Total sugars, per cent | Ratio of total sugars to total soluble solids |
|---|---|---|---|
| 1 | 11.85 | 8.12 | 0.685 |
| 2 | 12.85 | 9.83 | 0.765 |
| 3 | 11.15 | 8.27 | 0.741 |
| 6 | 12.40 | 8.86 | 0.715 |
| 7 | 11.50 | 9.78 | 0.850 |
| 11 | 11.30 | 8.72 | 0.771 |
| 12 | 11.85 | 9.43 | 0.796 |
| 13 | 11.60 | 9.20 | 0.798 |
| 14 | 11.30 | 8.69 | 0.769 |
| 15 | 12.00 | 9.23 | 0.769 |
| 16 | 12.10 | 9.70 | 0.801 |
| 17 | 10.30 | 9.18 | 0.891 |
| 18 | 11.90 | 9.23 | 0.691 |
| 19 | 11.85 | 9.97 | 0.841 |
| 20 | 10.85 | 9.06 | 0.835 |
| 21 | 11.50 | 9.87 | 0.858 |
| 22 | 11.45 | 9.77 | 0.853 |
| 23 | 11.25 | 9.61 | 0.854 |
| 24 | 11.35 | 9.16 | 0.807 |

* Table from literature citation 7.

TABLE 3
RELATION OF TOTAL SOLUBLE SOLIDS AND SUGARS IN MATURE FRUITS OF SEVERAL WATERMELON VARIETIES IN 1934 AND 1935

| Variety | Number of fruits | Total soluble solids, per cent | Sugars, per cent | | | Ratio of total sugars to total solids |
|---|---|---|---|---|---|---|
| | | | Total | Reducing | Sucrose | |
| Determinations of 1934 | | | | | | |
| California Klondike No. 3 | 20 | 11.3 | 9.37 | 5.29 | 4.08 | 0.829 |
| Klondike (commercial) | 20 | 11.3 | 9.23 | 5.84 | 3.39 | .817 |
| California Klondike No. 8 | 20 | 10.9 | 9.19 | 5.28 | 3.91 | .843 |
| California Klondike No. 1 | 20 | 10.5 | 9.04 | 5.12 | 3.92 | .861 |
| Iowa Belle | 20 | 10.4 | 8.95 | 5.22 | 3.73 | .861 |
| Pride of Muscatine | 20 | 9.7 | 8.11 | 6.20 | 1.91 | 0.836 |
| Determinations of 1935 | | | | | | |
| Striped Klondike No. 11 | 20 | 12.4 | 10.50 | 5.82 | 4.68 | 0.847 |
| California Klondike No. 3 | 25 | 11.6 | 10.04 | 5.80 | 4.24 | .866 |
| Long Mountain | 15 | 11.1 | 9.54 | 4.88 | 4.66 | .859 |
| Stone Mountain | 25 | 11.0 | 9.46 | 5.82 | 3.64 | .860 |
| Iowa Belle | 35 | 10.9 | 9.42 | 5.50 | 3.92 | .864 |
| Golden Honey | 10 | 10.1 | 8.81 | 5.66 | 3.15 | .873 |
| Pride of Muscatine | 30 | 9.9 | 8.71 | 6.58 | 2.13 | .880 |
| Thurmond Grey | 25 | 10.2 | 8.55 | 5.60 | 2.95 | .838 |
| Tom Watson | 30 | 10.4 | 8.45 | 4.49 | 2.96 | .813 |
| Hybrid 62 | 32 | 9.1 | 8.00 | 6.00 | 2.00 | 0.879 |

Similar determinations were made in 1934 and 1935, using mature fruits of many important commercial varieties. The results of these determinations are presented in table 3. They show a close correlation of total soluble solids and total sugars. The ratios of total sugars to total soluble solids varied from 0.813 to 0.879, with Tom Watson lowest in ratio among the ten varieties tested in 1935.

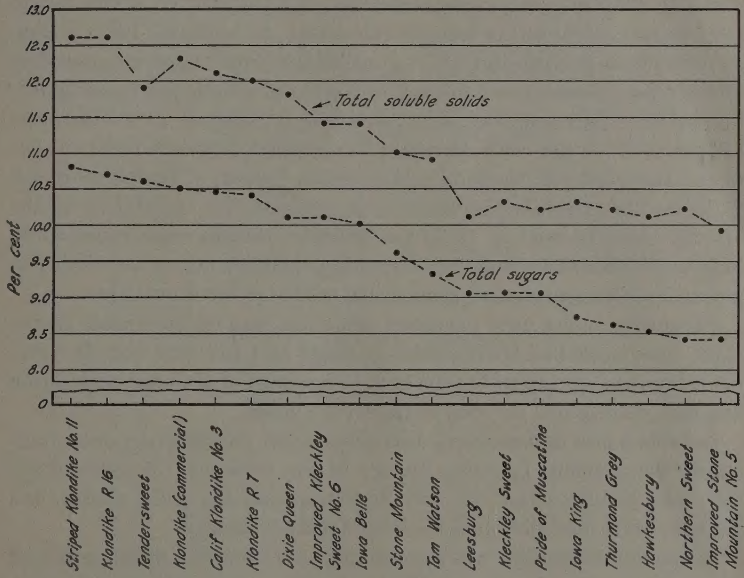


Fig. 2.—Indicating approximately uniform variation in content of total soluble solids and sugars for nineteen varieties grown in 1937. Note that the Klondike types were higher in sugar than Tom Watson and Thurmond Grey.

Certain previously untested varieties were included in the 1937 studies, and the percentage of total soluble solids and of total sugars for each is presented graphically in figure 2. It is evident that the trend in refractometric readings follows closely the trend in sugar content as determined chemically for the different varieties investigated, which gives proof of the interdependence of refractometric readings and sugar content. The average of the results for figure 2 indicate that approximately 85 per cent of the total soluble solids in extracted watermelon juice consists of sugars. The hand refractometer gives a reliable measurement of the total dissolved solids in juices from mature watermelons.

Because a rather constant ratio exists between total soluble solids and sugars, the authors believe that this instrument can be used to determine the relative sweetness of watermelons.

## INBREEDING IN RELATION TO TOTAL SOLUBLE SOLIDS

The following discussion pertaining to individual fruits refers not to total sugar content but to total soluble solids. As indicated later, if date of planting is delayed until mid-June, fruits from the same plant frequently vary as much as 2 to 3 per cent in total soluble solids. By planting in late April or May, this variation is reduced to a maximum difference of 1.6 per cent. As would be expected, however, plants of the same variety vary in the total soluble solids content of fruits produced. It seemed worthwhile therefore to investigate the variability of the several varieties used in 1937, particularly because some represented long-continued inbreeding within existing varieties, others were hybrids, and still others represented commercial seed at present available.

Frequency tables were prepared using the data on individual fruits. Each class contained fruits within a range of 1 per cent, that is 8.0 to 8.9, 9.0 to 9.9, etc., up to 14.0 to 14.9. Percentage of the total population was then determined for each of the seven classes.

In table 4 and figures 3 and 4, are presented the resulting data, indicating the previous breeding history of the varieties, the average per cent total soluble solids, the distribution among the seven classes, and the maximum and minimum readings for each variety.

Commercial Klondike was represented by a thorough mixture of seed secured from five companies. While the mean total soluble solids was 12.3 per cent, a large proportion of the fruits tested below 12.0 and above 13.0. Relatively few tested below 11.0 or above 14.0.

California Klondike No. 3 represented eleven generations of inbreeding within commercial Klondike. Comparing this variety with the parent variety (table 4 and fig. 3), it is evident that the only marked differences were in the two classes, 11.0 to 11.9 and 12.0 to 12.9. Inbreeding had reduced the percentage in the former class and very significantly increased the percentage in the latter. Extremes for the two varieties were practically identical.

Klondike R16, resistant to *Fusarium* wilt, represented six generations of inbreeding within commercial Klondike. In the class 11.0 to 11.9, a marked reduction was evident, in comparison with the parental variety. In class 12.0 to 12.9 the distribution was equally represented, but in

TABLE 4

RELATION OF INBREEDING TO TOTAL SOLUBLE SOLIDS IN CERTAIN WATERMELON VARIETIES IN 1937

| Variety | Previous history | Number of fruits | Average per cent total soluble solids | Per cent total soluble solids in individual fruits | | Percentage distribution of fruits in respective classes of per cent total soluble solids | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Minimum | Maximum | 8.0 to 8.9 | 9.0 to 9.9 | 10.0 to 10.9 | 11.0 to 11.9 | 12.0 to 12.9 | 13.0 to 13.9 | 14.0 to 14.9 |
| Klondike (commercial) | Commercial seed | 57 | 12.3 | 10.4 | 14.0 | 0.0 | 0.0 | 3.5 | 28.1 | 36.8 | 29.8 | 1.8 |
| California Klondike No. 3 | Inbred 11 generations | 50 | 12.1 | 10.0 | 14.2 | 0.0 | 0.0 | 4.0 | 18.0 | 54.0 | 24.0 | 0.0 |
| Klondike R16 | Inbred 6 generations | 50 | 12.6 | 10.6 | 14.2 | 0.0 | 0.0 | 2.0 | 12.0 | 36.0 | 46.0 | 4.0 |
| Klondike R7 | Iowa Belle×Klondike ($F_7$) | 50 | 12.0 | 10.8 | 14.6 | 0.0 | 0.0 | 4.0 | 26.0 | 54.0 | 14.0 | 2.0 |
| Iowa Belle | Inbred 8 generations | 40 | 11.4 | 10.0 | 12.8 | 0.0 | 0.0 | 32.5 | 47.5 | 20.0 | 0.0 | 0.0 |
| Kleckley Sweet | Commercial seed | 60 | 10.3 | 8.4 | 12.0 | 6.7 | 41.7 | 25.0 | 25.0 | 1.6 | 0.0 | 0.0 |
| Pride of Muscatine | Inbred 7 or 8 generations | 38 | 10.2 | 8.4 | 12.0 | 2.3 | 36.6 | 47.2 | 10.6 | 2.3 | 0.0 | 0.0 |
| Leesburg | Inbred 4 or 5 generations | 30 | 10.1 | 8.2 | 11.2 | 3.3 | 26.7 | 56.7 | 13.3 | 0.0 | 0.0 | 0.0 |
| Improved Kleckley Sweet No. 6 | Inbred 7 or 8 generations | 60 | 11.4 | 10.0 | 13.0 | 0.0 | 0.0 | 20.0 | 45.0 | 31.6 | 3.4 | 0.0 |
| Dixie Queen | Commercial seed | 50 | 11.8 | 10.0 | 13.2 | 0.0 | 0.0 | 10.0 | 36.0 | 50.0 | 4.0 | 0.0 |
| Stone Mountain | Commercial seed | 58 | 11.0 | 8.8 | 13.0 | 1.7 | 15.5 | 27.6 | 25.9 | 27.6 | 1.7 | 0.0 |
| Tom Watson | Commercial seed | 50 | 10.9 | 8.6 | 13.0 | 6.0 | 10.0 | 30.0 | 34.0 | 18.0 | 2.0 | 0.0 |
| Thurmond Grey | Commercial seed | 50 | 10.2 | 8.0 | 13.0 | 10.0 | 30.0 | 22.0 | 30.0 | 6.0 | 2.0 | 0.0 |
| Hawkesbury | Inbred 3 or 4 generations | 60 | 10.1 | 8.4 | 12.0 | 3.3 | 28.3 | 55.0 | 11.7 | 1.7 | 0.0 | 0.0 |
| Northern Sweet | Inbred 4 generations | 30 | 10.2 | 8.2 | 11.8 | 3.3 | 16.7 | 43.3 | 36.7 | 0.0 | 0.0 | 0.0 |
| Improved Stone Mountain No. 5 | Hybrid (probably $F_5$) | 30 | 9.9 | 8.8 | 11.0 | 3.3 | 46.7 | 40.0 | 10.0 | 0.0 | 0.0 | 0.0 |
| Striped Klondike No. 11 | Inbred 6 generations | 39 | 12.6 | 11.0 | 14.8 | 0.0 | 0.0 | 0.0 | 5.1 | 35.7 | 41.0 | 18.2 |

class 13.0 to 13.9 the percentage increased from 29.8 for the parental to 46.0 for the Klondike R16 variety.

The data indicate that inbreeding tends to stabilize a variety with respect to total soluble solids. This fact is not without precedent, since previous investigations (*4*) have determined similar effects of inbreeding upon other characters. Because total soluble solids and total sugars are closely correlated, it is evident that there exists greater uniformity of sweetness in both California Klondike No. 3 and Klondike R16 than in the parental variety commercial Klondike. The uniformity is evident enough to be commented upon by visitors who sample these varieties for their own pleasure.

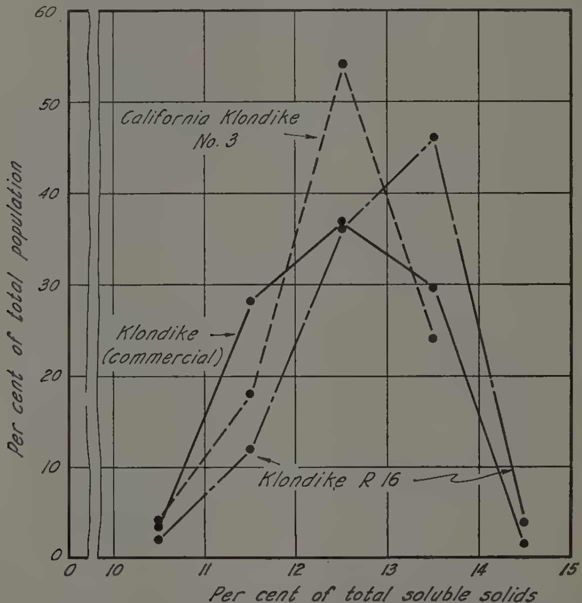


Fig. 3.—Frequency distribution, showing total soluble solids in Klondike (commercial), California Klondike No. 3, and Klondike R16 grown in 1937.

Next, consider Klondike R7 and the two parents used in its development—Iowa Belle and commercial Klondike (fig. 4). All of the fruits of Iowa Belle are in three classes from 10.0 to 10.9, 11.0 to 11.9, and 12.0 to 12.9. Approximately one third of them are in the first, almost one half

in the second, with only about one fifth in the third class. No fruits were in the two higher classes, the maximum testing only 12.8 per cent total soluble solids. Note, then, the distribution of Klondike R7. In classes 10.0 to 10.9 and 11.0 to 11.9, Klondike R7 shows a decided decrease when compared with Iowa Belle. The percentages for Iowa Belle and Klondike R7 in class 12.0 to 12.9 were 20.0 and 54.0, respectively. Comparing Klon-

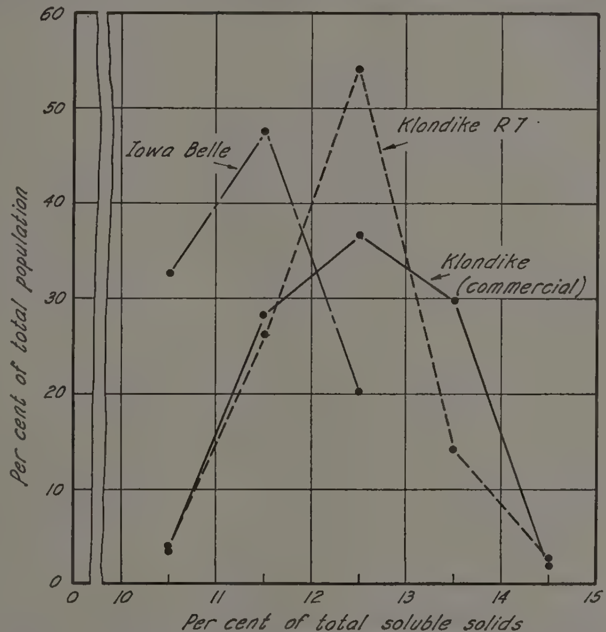


Fig. 4.—Frequency distribution, showing total soluble solids in Iowa Belle, Klondike (commercial), and Klondike R7, grown in 1937.

dike R7 with commercial Klondike, the two lower classes are identical, but in class 12.0 to 12.9, Klondike R7 shows an increase from 36.8 to 54.0 per cent. Klondike R7 had fewer fruits in class 13.0 to 13.9, but had a maximum of 14.6, whereas the maximum for commercial Klondike was 14.0. Therefore, by careful selection within a hybrid between strains of low and of high total sugar content, it is apparent that the high total sugar character may be recovered and stabilized. In fact, Klondike R7 and California Klondike No. 3 are approximately identical both in average total soluble solids and in class frequency.

Kleckley Sweet has long been an important watermelon variety, par-

ticularly for local use. It has been considered a variety of more than average sweetness. The data in table 4 do not support this belief. It is possible that, because attention has been focused upon wilt resistance in this variety, the ordinary wilt-susceptible stocks of Kleckley Sweet have not been so carefully selected as formerly. The seed used in 1937, however, represented a composite sample obtained by thoroughly mixing seed secured from five different seed companies who have handled this variety for many years.

In table 6, Kleckley Sweet is well down the list in total sugar content, being fourteenth among twenty varieties. In table 4, considering 60 fruits, it is likewise shown to be relatively low with an average total soluble solids of 10.3 per cent. Only one fruit tested above 12.0 and many below 9.0 with almost one half between 9.0 and 9.9 per cent.

The varieties, Pride of Muscatine, Leesburg, and Improved Kleckley Sweet No. 6 are wilt-resistant selections originating from commercial Kleckley Sweet. The data in table 4 indicate that, in general, Pride of Muscatine and Kleckley Sweet are similar in total soluble solids. Likewise, Leesburg is of the same constitution. With Improved Kleckley Sweet No. 6, however, there are some notable differences when compared with parental Kleckley Sweet. Whereas a total of 48.4 per cent of Kleckley Sweet tested below 10.0 per cent, all of the fruits of Improved Kleckley Sweet No. 6 were above this figure. Only one fruit of Kleckley Sweet tested above 12.0, but 35.0 per cent of the No. 6 strain was above this figure. Respective maximum figures for the two varieties were 12.0 and 13.0 for Kleckley Sweet and the No. 6 strain.

Thus with Klondike and Kleckley Sweet, it is evident that average total soluble solids content, if seriously considered in a program of selection, may not only be increased but may be made more uniform. Sugar content is not "all important" but high sugar content is particularly desirable in a watermelon.

The other varieties listed in table 4 need be mentioned but briefly, since they do not contribute evidence to the value of selection. Improved Stone Mountain No. 5 resulted from a cross of Stone Mountain with Japan 7 (not available for these tests). It is, however, decidedly lacking in sugar, and was used only because of its resistance to wilt. Improved Stone Mountain No. 5 is decidedly inferior to commercial Stone Mountain, not only in total soluble solids and sugar content but in other important fruit characters. It needs further breeding work, but is a valuable variety because of its resistance to wilt and its similarity in type to Stone Mountain.

Dixie Queen, although tested at Davis only in 1937, is a variety of

potential value. In rating of total soluble solids it was surpassed only by the Klondike strains and by Tendersweet. Furthermore, all its fruits tested above 10.0 with many well above 12.0 per cent. Other characters than high sugar content make this a valuable variety.

Whereas the Klondike strains, Dixie Queen, and Improved Kleckley Sweet No. 6 were usually well confined to adjacent three or four classes, note the spread with Tom Watson, Stone Mountain, Thurmond Grey, and Kleckley Sweet. Fruits of these varieties were found in six groups and with extremely low minima. Admittedly, a few fruits of these varieties tested as high as 13.0 per cent total soluble solids. Since the trends for the per cent total sugars and total soluble solids (fig. 2) are shown to be essentially alike, we may assume that the readings of the hand refractometer for the total soluble solids would indicate a similar change in the spread of the per cent of total sugars caused by inbreeding.

Conceivably, if breeders would inbreed within these varieties and carefully select for high total soluble solids content, superior strains could be developed. A logical procedure would be to cross these important varieties with certain of the wilt-resistant, high-sugar strains. In fact, a few breeders now have such work in progress. A vast majority of the varieties tested at Davis consistently produced from a few to many fruits testing above 13.0 per cent in total soluble solids. These varieties contain the genes for high sugar content. It remains for the breeder to segregate them, and to combine them with the genes responsible for other desirable characters. The hand refractometer will be invaluable in this procedure.

## RELATIVE TOTAL SOLUBLE SOLIDS AND SUGAR CONTENT OF VARIETIES

Comparative tests of many important commercial varieties and certain inbred strains were made from 1933 to 1937, inclusive. Seven varieties were compared in 1933 and the results are presented in table 5. California Klondike No. 3 proved sweetest of the varieties tested, with Thurmond Grey and Pride of Muscatine significantly lower in both total soluble solids and sugars.

The trials in 1934 included four Klondike strains—three developed at this station (*4*)—in addition to Iowa Belle, and Pride of Muscatine. The resulting data are presented in figure 5. Here again the Klondike strains were relatively high and Pride of Muscatine relatively low in total soluble solids and sugars. The data in figure 5 also indicate that the ratio of sugar to total soluble solids was essentially the same with fruits harvested on August 21 and September 6.

In 1935 tests were more extensive than those of previous years, as they included such important commercial varieties as Tom Watson, Thurmond Grey, and Stone Mountain. The results are presented graphically in figure 6 and again indicate that the Klondike strains head the list in total soluble solids and total sugar content, whereas Thurmond Grey, Tom Watson, and Pride of Muscatine were low. The intermediate varieties were Stone Mountain, Northern Sweet, Long Mountain, and Yellow-fleshed Ice Cream. Winter Queen and Hybrid 62 were extremely low in

TABLE 5
TOTAL SOLUBLE SOLIDS AND SUGARS IN MATURE WATERMELON FRUITS IN 1933

| Variety | Total soluble solids, per cent | Sugars, per cent | | | Ratio of total sugars to total soluble solids |
|---|---|---|---|---|---|
| | | Total | Reducing | Sucrose | |
| California Klondike No. 3 | 11.8 | 10.09 | 4.39 | 5.70 | 0.855 |
| California Klondike No. 8 | 11.3 | 9.30 | 5.62 | 3.68 | .823 |
| Klondike (commercial) | 11.4 | 8.88 | 5.68 | 3.20 | .779 |
| Iowa Belle | 10.8 | 8.76 | 5.38 | 3.38 | .811 |
| Thurmond Grey | 10.5 | 7.97 | 4.21 | 3.76 | .759 |
| Iowa King | 9.1 | 7.30 | 3.69 | 3.61 | .802 |
| Pride of Muscatine | 8.9 | 7.13 | 5.53 | 1.60 | 0.801 |

total sugar; the latter represents a selection by the senior author to develop a low-sugar strain for inheritance studies.

The trials in 1936 consisted mainly of wilt-resistant selections in comparison with various Klondike strains and several commercial varieties used in 1935. Since the results were in agreement with those of 1935 they are not tabulated. Again, however, strains of the Klondike group were high while Tom Watson and Thurmond Grey were low in content of both total soluble solids and total sugars. Many of the resistant selections scored as high as California Klondike No. 3, but none as high as Striped Klondike No. 11. The latter is the sweetest variety tested and is a valuable variety in the watermelon breeding program. Klondike R7 (*6*), a recently introduced wilt-resistant variety, was approximately the same as California Klondike No. 3 in total sugars and total soluble solids.

Because of increased interest in the several recently developed watermelon varieties which resist *Fusarium* wilt, these were compared in 1937; and included with these were the eight more important wilt-susceptible varieties. The developmental history of all available wilt-resistant varieties was recently described by Porter (*6*). Iowa 112 is an experimental strain developed at the Iowa station, outstanding because of its brilliant red flesh color. The resulting comparisons of total sugars

and total soluble solids for 1937 are presented in table 6. Striped Klondike No. 11 was the sweetest variety tested; in fact, of the six sweetest varieties, five were of Klondike type. Tendersweet, a wilt-susceptible, yellow-fleshed variety, was in third position. It was grown at Davis for the first time in 1937, and manifested exceptionally high quality for a

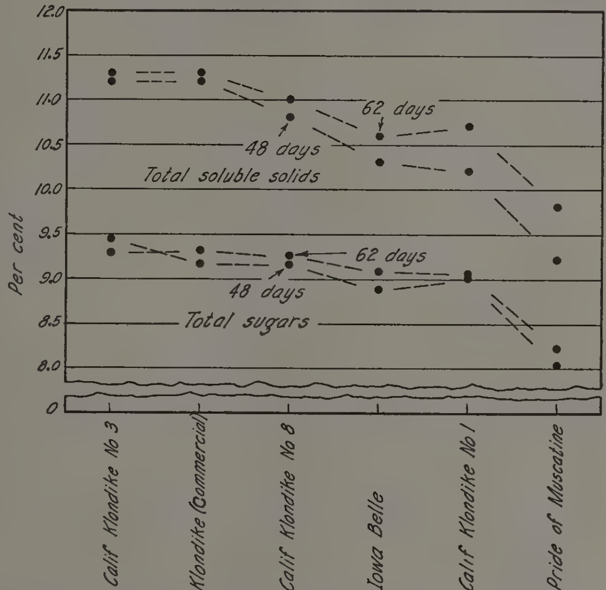


Fig. 5.—Total soluble solids and total sugars in six varieties grown in 1934, harvested on August 21 (48 days) and September 6 (62 days).

yellow-fleshed type. It matured with Dixie Queen and soon after Northern Sweet.

The wilt-resistant types, arranged in decreasing order with respect to sugar content were as follows: Klondike R16, Klondike R7, Improved Kleckley Sweet No. 6, Iowa Belle, Iowa 112, Leesburg, Pride of Muscatine, Iowa King, Hawkesbury, and Improved Stone Mountain No. 5. Wilt-susceptible varieties similarly arranged were as follows: Striped Klondike No. 11, Tendersweet, commercial Klondike, California Klondike No. 3, Dixie Queen, Stone Mountain, Tom Watson, Kleckley Sweet, Thurmond Grey, and Northern Sweet.

Admittedly, characters other than high total sugar content influence the grower in his choice of varieties. Results of varietal trials conducted

throughout the watermelon sections of the United States have indicated that although the various Klondike types are not generally adapted except in California and Arizona, they are unquestionably of high quality. Breeders are now using Klondike R7 as parental material in developing resistant, high-quality varieties which are locally adapted. Of the important wilt-susceptible varieties grown east of the Rocky Moun-

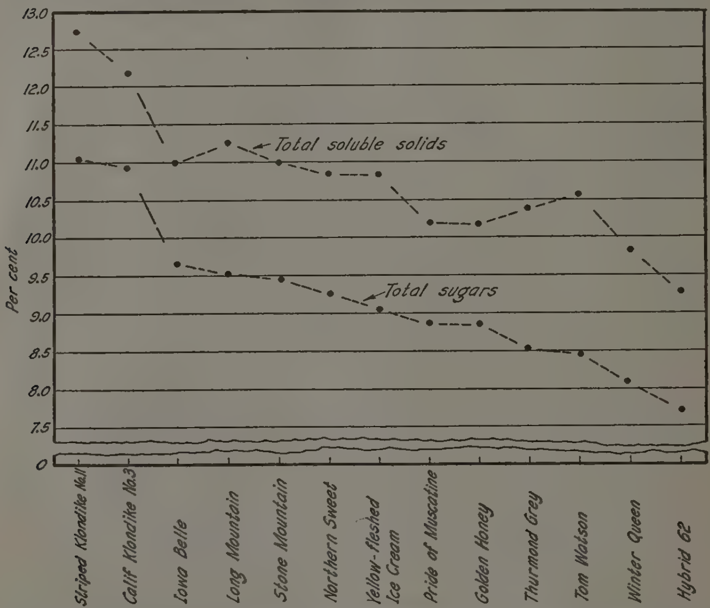


Fig. 6.—Total soluble solids and total sugars for thirteen varieties grown in 1935. Note the relative position of the Klondike types in comparison with Tom Watson and Thurmond Grey.

tains, Dixie Queen and Stone Mountain are the sweetest. Tom Watson, Kleckley Sweet, and Thurmond Grey are widely planted; in fact Tom Watson is the most important variety now used in the United States. These three varieties contain less total sugars than the Klondike types and less than improved Kleckley Sweet No. 6.

Klondike R16 has not been released to the trade because it is inferior in flesh texture to Klondike R7. Its tough rind, resistance, and high total sugar content make it a valuable type for breeding purposes. Leesburg, a recent introduction by Walker (*10*), when grown at Davis, was

TABLE 6

TOTAL SOLUBLE SOLIDS AND SUGARS IN ALL WILT-RESISTANT AND ALL IMPORTANT WILT-SUSCEPTIBLE VARIETIES OF WATERMELONS IN 1937

| Variety | Reaction to wilt* | Number of fruits | Total soluble solids, per cent | | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Average of all fruits | Composite liter samples | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| Striped Klondike No. 11 | S | 39 | 13.0 | 12.6 | 10.77 | 3.93 | 6.84 | 0.855 | 1.740 |
| Klondike R16 | R | 50 | 12.8 | 12.6 | 10.74 | 5.89 | 4.85 | .853 | 0.823 |
| Tendersweet | S | 9 | 12.1 | 11.9 | 10.63 | 4.67 | 5.96 | .893 | 1.277 |
| Klondike (commercial) | S | 57 | 12.4 | 12.3 | 10.49 | 3.65 | 6.84 | .853 | 1.873 |
| California Klondike No. 3 | S | 50 | 12.3 | 12.1 | 10.48 | 3.50 | 6.97 | .867 | 1.992 |
| Klondike R7 | R | 50 | 12.1 | 12.0 | 10.39 | 4.09 | 6.30 | .866 | 1.541 |
| Improved Kleckley Sweet No. 6 | R | 60 | 11.7 | 11.4 | 10.13 | 3.43 | 6.70 | .889 | 1.953 |
| Dixie Queen | S | 50 | 11.8 | 11.8 | 10.12 | 4.86 | 5.26 | .857 | 1.082 |
| Iowa Belle | R | 40 | 11.5 | 11.4 | 10.03 | 4.22 | 5.81 | .880 | 1.377 |
| Stone Mountain | S | 58 | 11.0 | 11.0 | 9.64 | 4.74 | 4.90 | .877 | 1.033 |
| Tom Watson | S | 50 | 10.9 | 10.9 | 9.34 | 3.82 | 5.52 | .857 | 1.444 |
| Iowa 112 | R | 13 | 11.3 | 10.8 | 9.18 | 4.43 | 4.75 | .850 | 1.072 |
| Leesburg | R | 30 | 10.1 | 10.1 | 9.06 | 3.65 | 5.41 | .897 | 1.482 |
| Kleckley Sweet | S | 60 | 10.0 | 10.3 | 9.06 | 4.80 | 4.26 | .879 | 0.888 |
| Pride of Muscatine | R | 38 | 10.0 | 10.2 | 9.04 | 5.84 | 3.20 | .886 | 0.548 |
| Iowa King | R | 17 | 10.1 | 10.3 | 8.74 | 3.56 | 5.18 | .849 | 1.454 |
| Thurmond Grey | S | 50 | 10.3 | 10.2 | 8.65 | 3.80 | 4.85 | .848 | 1.277 |
| Hawkesbury | R | 61 | 10.1 | 10.1 | 8.56 | 3.61 | 4.95 | .847 | 1.371 |
| Northern Sweet | S | 30 | 10.4 | 10.2 | 8.45 | 4.47 | 3.98 | .828 | 0.890 |
| Improved Stone Mountain No. 5 | R | 30 | 9.9 | 9.9 | 8.45 | 4.52 | 3.93 | 0.853 | 0.869 |

* The letters "R" and "S" mean wilt-resistant and wilt-susceptible, respectively.

low in total sugar content but its resistance, tough rind, and fruit type make it a valuable variety for southern growers. Hawkesbury, also recently developed (*11*), is low in total sugar, but again is admirably adapted to resist rough handling. Furthermore, it is prolific, wilt-resistant, and of exceptionally uniform type, resembling Thurmond Grey in external fruit characters. It could also be used advantageously as breeding stock.

## SUGAR FORMATION DURING FRUIT DEVELOPMENT

In the various strains of the Klondike variety grown at Davis, the fruits were mature approximately 45 days after anthesis. In 1933, female flowers were tagged and dated at anthesis and harvested when they were 30, 50, and 65 days old. The fruits were cut immediately and composite juice samples tested for total soluble solids, reducing sugars, and sucrose. The results appear in table 7. The total soluble solids increased from the thirtieth to the fiftieth day but after 50 days the increase was not significant. The same trend is evident in sugar increase. Ratios of total sugars to total soluble solids remained nearly constant, whether considering immature, mature, or overripe fruits. One important variation detected was that concerned with the ratio of sucrose to reducing sugars. This ratio for immature, mature, and overripe fruits was 0.181, 0.777, and 1.644, respectively.

TABLE 7

Degree of Maturity as Related to the Ratios of Total Sugars to Total Soluble Solids and of Sucrose to Reducing Sugars in Composite Samples of California Klondike No. 3 in 1933

| Degree of maturity (days after anthesis) | Total soluble solids, per cent | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|
| | | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| Immature, average approximately 30 days... | 10.08 | 7.96 | 6.74 | 1.22 | 0.789 | 0.181 |
| Mature, average 50 days. | 11.53 | 9.10 | 5.12 | 3.98 | 0.789 | 0.777 |
| Overripe, average 65 days | 11.85 | 9.23 | 3.49 | 5.74 | 0.779 | 1.644 |

Similar tests were made in 1934, using four different Klondike strains as well as Iowa Belle and Pride of Muscatine. Again fruits were tagged at anthesis and harvested when either 48 or 62 days old. Hand-refractometer readings and chemical analyses were made as in 1933, with the results appearing in table 8. Considering each variety separately there was only slight variation in either total soluble solids or total sugars

TABLE 8

TOTAL SOLUBLE SOLIDS AND SUGARS IN SIX WATERMELON VARIETIES AND STRAINS IN 1934

| Variety | Average age of fruits, in days after anthesis* | Number of fruits sampled | Total soluble solids, per cent | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| California Klondike No. 3 | 48 | 20 | 11.2 | 9.29 | 6.49 | 2.80 | 0.829 | 0.431 |
| Klondike (commercial) | 48 | 15 | 11.2 | 9.30 | 6.46 | 2.84 | .830 | 0.439 |
| California Klondike No. 8 | 48 | 20 | 10.8 | 9.24 | 6.45 | 2.79 | .855 | 0.432 |
| California Klondike No. 1 | 48 | 15 | 10.2 | 9.04 | 6.52 | 2.52 | .886 | 0.386 |
| Iowa Belle | 48 | 15 | 10.3 | 9.09 | 5.53 | 3.56 | .883 | 0.644 |
| Pride of Muscatine | 48 | 20 | 9.2 | 8.21 | 6.84 | 1.37 | .893 | 0.200 |
| California Klondike No. 3 | 62 | 15 | 11.3 | 9.44 | 4.08 | 5.36 | .835 | 1.313 |
| Klondike (commercial) | 62 | 20 | 11.3 | 9.16 | 5.22 | 3.94 | .811 | 0.755 |
| California Klondike No. 8 | 62 | 20 | 11.0 | 9.15 | 4.12 | 5.03 | .832 | 1.221 |
| California Klondike No. 1 | 62 | 15 | 10.7 | 9.04 | 3.72 | 5.32 | .845 | 1.430 |
| Iowa Belle | 62 | 20 | 10.6 | 8.81 | 4.91 | 3.90 | .831 | 0.794 |
| Pride of Muscatine | 62 | 15 | 9.8 | 8.01 | 5.57 | 2.44 | 0.817 | 0.438 |

* At 48 days the fruits are considered ripe; at 62 days, distinctly overripe.

when the 48- and 62-day fruits were compared. Thus, total soluble solids and total sugars reach maximum development when the fruits are ready for the consumer. Also, the ratio of total sugars to total soluble solids remains remarkably constant when mature and overripe fruits are compared. Considering each variety separately, the only significant change appears to be in the ratio of sucrose to reducing sugars. Thus this ratio for California Klondike No. 3 increased from 0.431 to 1.313; for California Klondike No. 1 from 0.386 to 1.430; and for Iowa Belle from 0.644 to 0.794. It will be seen from the data in table 8 that during the 14-day interval the increase in sucrose amounted to 0.34 per cent in the case of Iowa Belle, and 1.07 per cent in the case of Pride of Muscatine. These increases are much less than for California Klondike Nos. 1, 3, and 8, indicating that the sucrose formation in Iowa Belle and Pride of Muscatine was comparatively slow. Possibly this observation explains the reason why overripe fruits, especially in the latter variety, seem to lack sweetness when eaten.

The data further show a pronounced decrease in reducing sugars, accompanying the increase of sucrose.

Still another test was conducted in 1934 when fruits of several strains of Klondike, tagged and dated at anthesis, were harvested when 40, 50, and 60 days old. The usual determinations were made, and the results appear in table 9. The strains designated as California Klondike Nos. 1, 3, and 8 were described in 1933 (*4*). The seed of commercial Klondike was a composite sample made by blending seed furnished by four seed companies.

The percentage of total soluble solids increased between the fortieth and fiftieth day, in 1934, for all strains. The same statement applies to the percentage of total sugars, with a consistent ratio of total sugars to total soluble solids. As in previous trials, the ratio of sucrose to reducing sugar increased significantly from the fortieth through the fiftieth and to the sixtieth day for all strains.

The procedure in 1935 varied from that of the two previous years in that fruits were harvested after 10, 15, 20, 25, 30, 35, 40, and 45 days from date of anthesis. They were cut immediately after harvest and tested individually with the hand refractometer for total soluble solids. The expressed juice composites were also tested and finally sugar determinations were made. The results are presented in table 10.

The arithmetical average of the per cent of total soluble solids for each group of fruit agrees closely with that determined for the composite sample; differences are well within the range of experimental error. At 10 and 15 days the flesh is white, at 20 it has a pale-pink tinge adjacent

TABLE 9

SUGAR FORMATION IN SEVERAL KLONDIKE STRAINS IN 1934

| Strain or Variety | Number of fruits sampled | Average age of fruits, in days after anthesis | Total soluble solids, per cent | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| Klondike (commercial) | 20 | 40 | 10.23 | 8.54 | 5.60 | 2.94 | 0.835 | 0.525 |
| | 16 | 50 | 11.36 | 9.30 | 5.81 | 3.49 | .819 | 0.601 |
| | 24 | 60 | 11.30 | 9.61 | 4.85 | 4.76 | .851 | 0.981 |
| California Klondike No. 1 | 13 | 40 | 10.32 | 8.18 | 4.96 | 3.22 | .793 | 0.649 |
| | 14 | 50 | 11.50 | 9.55 | 5.89 | 3.66 | .831 | 0.621 |
| | 20 | 60 | 11.63 | 9.43 | 4.72 | 4.71 | .811 | 0.999 |
| California Klondike No. 3 | 20 | 40 | 10.46 | 8.22 | 5.48 | 2.74 | .786 | 0.500 |
| | 15 | 50 | 11.41 | 9.25 | 5.31 | 3.94 | .811 | 0.742 |
| | 18 | 60 | 11.26 | 9.27 | 4.91 | 4.36 | .823 | 0.888 |
| California Klondike No. 5 | 11 | 40 | 10.54 | 8.30 | 5.19 | 3.11 | .787 | 0.599 |
| | 20 | 50 | 10.84 | 9.01 | 4.87 | 4.14 | .831 | 0.850 |
| | 15 | 60 | 10.79 | 9.12 | 4.34 | 4.78 | .845 | 1.102 |
| California Klondike No. 8 | 9 | 40 | 10.23 | 8.70 | 5.12 | 3.58 | .851 | 0.699 |
| | 14 | 50 | 11.25 | 10.00 | 5.55 | 4.45 | .889 | 0.801 |
| | 22 | 60 | 11.58 | 10.00 | 4.02 | 5.98 | 0.864 | 1.487 |

to the seeds, at 25 and 30 it is usually rather uniformly pink. Then, as it matures, the color gradually intensifies, reaching a maximum at approximately 45 days. At 20 days the refractometric reading is higher in juice adjacent to the seeds than in the juice of the heart flesh.

The data for 1935, as given in table 10, are self explanatory; they show a gradual increase in both total soluble solids and total sugars from the tenth to the fortieth day. No sucrose was detectable until the

TABLE 10

TOTAL SOLUBLE SOLIDS AND SUGARS IN FRUITS CUT IMMEDIATELY AFTER HARVEST; CALIFORNIA KLONDIKE NO. 1, 1935

| Average age of fruits, in days after anthesis | Number of fruits | Total soluble solids, per cent | | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|---|---|
| | | Arithmetical average | Composite sample | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| 10 | 6 | 3.18 | 3.2 | 2.40 | 2.40 | 0.00 | 0.750 | ..... |
| 15 | 10 | 3.64 | 4.0 | 2.79 | 2.79 | 0.00 | .697 | ..... |
| 20 | 9 | 5.60 | 5.8 | 4.55 | 4.55 | 0.00 | .785 | ..... |
| 25 | 10 | 7.71 | 7.8 | 6.32 | 6.32 | 0.00 | .811 | ..... |
| 30 | 10 | 8.70 | 8.9 | 7.38 | 7.20 | 0.18 | .829 | 0.025 |
| 35 | 9 | 10.40 | 10.2 | 8.96 | 7.61 | 1.35 | .879 | 0.177 |
| 40 | 10 | 11.70 | 12.0 | 10.24 | 7.29 | 2.95 | .854 | 0.405 |
| 45 | 10 | 11.80 | 11.6 | 9.61 | 5.11 | 4.50 | 0.829 | 0.881 |

thirtieth day when it amounted to 0.18 per cent. As stated previously, there was a rapid change in the ratio of sucrose to reducing sugar with advancing maturity. From the thirtieth to the forty-fifth day, this ratio increased from 0.025 to 0.881.

The 1937 procedure was the same as that of 1935. Although Klondike R7 was used instead of California Klondike No. 1, the developmental trend during the two years was practically identical, the solids increasing from 3.9 at 10 to 12.1 per cent at 50 days; these data were not tabulated.

## CHANGES IN SUGAR CONTENT OF STORED WATERMELONS

Data are also available on the development of total soluble solids and sugars, both reducing sugars and sucrose, in detached fruits which varied in age when picked and stored.

In a preliminary study on storage of watermelons conducted during 1934, female flowers were tagged and dated at anthesis and the fruits harvested beginning July 16, at 5-day intervals from the tenth to the

sixtieth day. All fruits were stored at room temperature, until September 15, when they were cut, sampled in the usual way, and chemical analyses made at once. The resulting data for total soluble solids, total sugars, and sucrose are presented in figure 7. The trends for total soluble solids and total sugars are essentially alike, in agreement with previous experience. No sucrose was found in either the 10- or 15-day fruits and only 0.31 per cent in the 20-day fruits. Each of these three groups

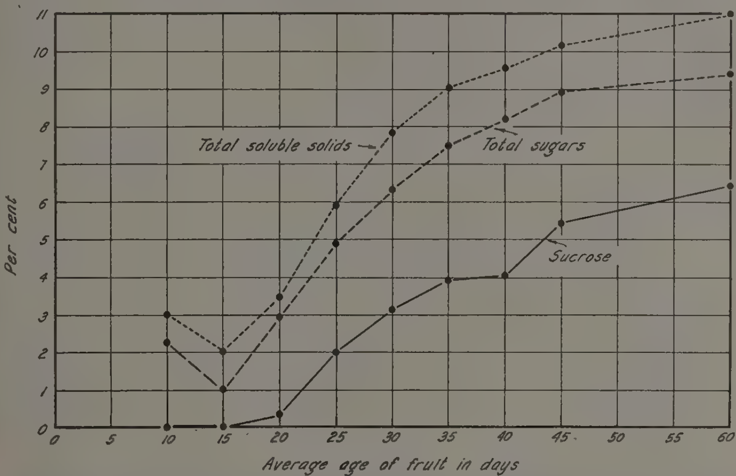


Fig. 7.—Showing development of total soluble solids and sugars in California Klondike No. 1 grown in 1934, beginning with the tenth and extending to the sixtieth day from anthesis. Data for stored fruits, all cut on September 15.

had been in storage for 61, 50, and 49 days, respectively. In the 25-day group sucrose had increased to 1.92 per cent; thereafter there was a rather gradual increase until the fortieth day, then a decided increase to the sixtieth day. At 60 days the ratio of sucrose to reducing sugar was 2.009, whereas on the forty-fifth day it was only 1.498.

A more detailed storage test was conducted in 1935 and the results for total sugars and sucrose are graphically represented in figure 8. It pictures the percentage of sucrose and total sugars for fruits cut and sampled when harvested and for fruits which were stored for some time after harvesting. It is evident that there was a loss in total sugar content during storage for all samples, since the curve for total sugars in stored fruits lies wholly below the curve for freshly picked melons. The actual difference varied from 0.87 for 30-day fruits to 1.76 per cent for 40-day fruits.

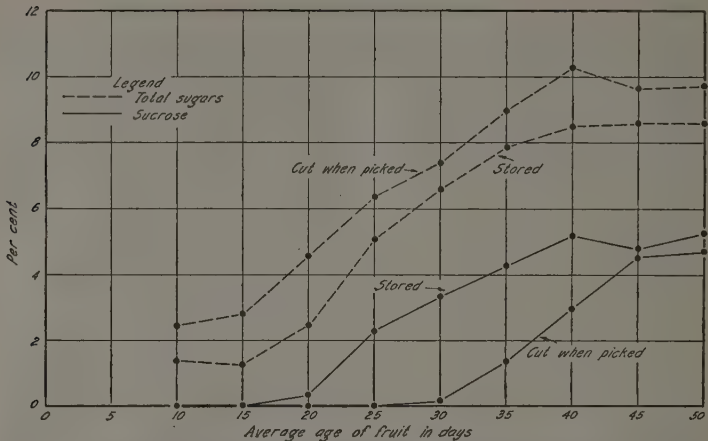


Fig. 8.—Comparison for both sucrose and total sugars in freshly harvested and stored fruits of California Klondike No. 1 grown in 1935.

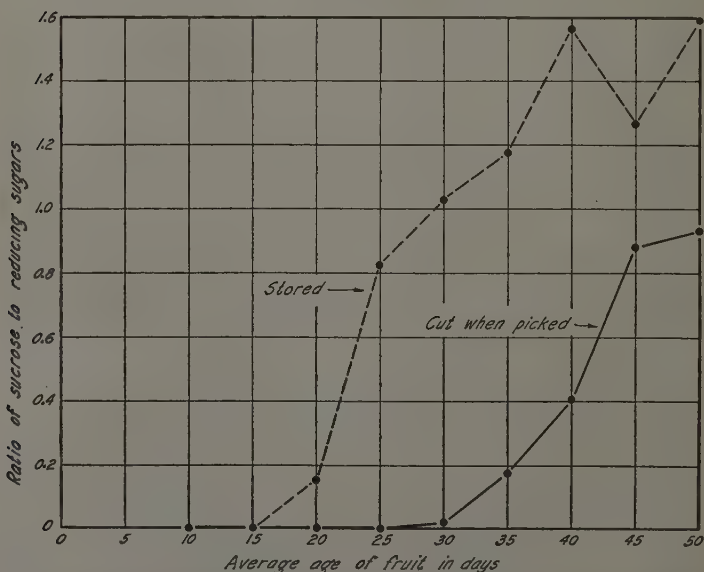


Fig. 9.—Indicating the ratio of sucrose to reducing sugars for freshly harvested and stored fruits of California Klondike No. 1 grown in 1935.

The sucrose picture is different, since the graph for sucrose in stored fruits lies entirely above that for fruits which were cut immediately after harvest. This indicates that the sucrose content of all fruit increased during storage. In order to get a true picture of the sucrose increase due to storage the percentage of sucrose found in fresh fruits must be subtracted from that found in the stored fruits. These percentage increases from the twentieth through to the fiftieth day are as follows: 0.33, 2.32, 3.18, 2.96, 2.24, 0.32, and 0.48. It is clearly evident that

TABLE 11

SUGAR DEVELOPMENT IN STORED KLONDIKE R7 WATERMELONS IN 1937

| Age of fruits, in days after anthesis | Number of fruits | Total soluble solids, per cent | | Sugars, per cent | | | Ratios | |
|---|---|---|---|---|---|---|---|---|
| | | Arith-metical average | Com-posite sample | Total | Reducing | Sucrose | Total sugars to total soluble solids | Sucrose to reducing sugars |
| 10 | 8 | 3.8 | 3.6 | 2.90 | 2.69 | 0.21 | 0.806 | 0.078 |
| 15 | 8 | 3.0 | 3.0 | 2.41 | 2.21 | 0.20 | .803 | 0.091 |
| 20 | 10 | 5.2 | 5.0 | 4.20 | 2.80 | 1.40 | .840 | 0.500 |
| 30 | 10 | 8.6 | 8.0 | 6.15 | 2.88 | 3.27 | .769 | 1.135 |
| 35 | 9 | 9.0 | 9.0 | 7.28 | 3.22 | 4.06 | .809 | 1.261 |
| 40 | 6 | 10.5 | 10.4 | 8.73 | 3.01 | 5.72 | .838 | 1.900 |
| 45 | 5 | 9.8 | 10.0 | 8.77 | 3.36 | 5.41 | .877 | 1.610 |
| 50 | 4 | 10.4 | 11.0 | 9.25 | 3.23 | 6.02 | 0.841 | 1.863 |

sucrose increased greatly in storage up to the thirtieth day followed by a decline which became very pronounced in the forty-fifth or fiftieth days.

The graph (fig. 9) for the ratio of sucrose to reducing sugars in stored fruits lies entirely above that for fruits cut immediately after picking. This is to be expected from the information presented in figure 8, in which it was shown that total sugars decreased and sucrose increased for all fruits during storage.

Because no sucrose was found in the 25-day freshly harvested fruits, the ratio of sucrose to reducing sugars is necessarily zero. Therefore, owing to the large increase in sucrose accompanied by a decrease in reducing sugars, this ratio increased until for the 50-day fruits it became 0.932. In the stored fruits, however, the ratio of sucrose to reducing sugars on the twentieth day was 0.175, and on the fiftieth day 1.596.

Again, in 1937, similar comparisons were made and the results are presented in table 11. In general, these results agree essentially with those previously discussed. One significant exception should, however, be noted. While in 1934 and 1935 no sucrose was found in 10- or 15-day

stored fruits, 0.21 and 0.20 per cent were found in the 10- and 15-day fruits in the 1937 tests. A possible explanation is the fact that Klondike R7 was used in 1937 whereas California Klondike No. 1 and No. 3 had been previously used. Possibly sucrose formation varies among varieties.

## THE DEXTROSE-LEVULOSE CONTENT

Only one year's data are available on the kinds of reducing sugars in watermelons. These sugars were determined by the Lothrop-Holmes (*3*) method, and it is assumed that the results indicate the amounts of reducing sugars present in the form of dextrose and levulose. These results are presented in table 12 for fruits of California Klondike No. 1 from 10 to 50 days old, and for more mature fruits of the other varieties indicated. While these data for dextrose-levulose ratios are not sufficiently conclusive for comparison of varieties, a considerable difference is apparent, particularly between Winter Queen and Hybrid 62 at maturity. In the former there was a preponderance of levulose while in the latter the two kinds of sugar were approximately equal.

In the maturing fruits of California Klondike No. 1, there was a steady, although not a sharp increase in the dextrose-levulose ratio, increasing from 0.268 for 10-day fruits to 0.704 for 50-day fruits. Thus, while there is an actual increase of both kinds of sugar from the tenth to the fiftieth day, dextrose showed a greater percentage increase than levulose.

## EFFECTS OF ENVIRONMENT UPON TOTAL SOLUBLE SOLIDS AND TOTAL SUGAR CONTENT

The discussion thus far has suggested that the total sugar content of watermelon varieties is governed entirely by hereditary factors. There is abundant evidence that high sugar content is hereditary. There is also some evidence, though meager, that the total sugar content of a variety differs under varying environmental conditions. The watermelon is normally considered a warm-weather plant, further favored by long days. Growers usually avoid the heavy soil types as well as peat and muck soils. Watermelons are said not to thrive when grown near the ocean, where the mean tempertaure during the growing season is significantly lower than in the interior valleys.

Experimental evidence that a genetically pure strain may vary in total sugar content with time of maturity may be summed up as follows. Each year, at Davis, planting of Klondike R7 on wilt-infested soil is

TABLE 12

TOTAL SOLUBLE SOLIDS AND RATIOS OF VARIOUS TYPES OF REDUCING SUGARS IN WATERMELONS AT DIFFERENT AGES; 1935

| Variety | Number of fruits | Average age of fruits, in days after anthesis | Total soluble solids, per cent | Reducing sugars, per cent | | | Ratios | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Dextrose | Levulose | Total | Dextrose to levulose | Dextrose to reducing | Levulose to reducing |
| California Klondike No. 1 | 10 | 10 | 2.2 | 0.29 | 1.08 | 1.37 | 0.268 | 0.212 | 0.788 |
| | 9 | 15 | 2.0 | 0.29 | 0.96 | 1.25 | .302 | .232 | .768 |
| | 10 | 20 | 3.8 | 0.59 | 1.55 | 2.14 | .380 | .275 | .725 |
| | 10 | 30 | 8.4 | 0.95 | 2.25 | 3.20 | .422 | .297 | .703 |
| | 10 | 35 | 9.8 | 1.24 | 2.35 | 3.59 | .528 | .345 | .655 |
| | 9 | 40 | 10.6 | 1.19 | 2.12 | 3.31 | .561 | .362 | .640 |
| | 10 | 45 | 10.6 | 1.45 | 2.33 | 3.78 | .622 | .384 | .617 |
| | 6 | 50 | 11.0 | 1.39 | 1.98 | 3.37 | .703 | .402 | .588 |
| California Klondike No. 3 | 10 | 50 | 12.0 | 1.62 | 2.68 | 4.30 | .605 | .377 | .623 |
| Striped Klondike No. 11 | 10 | 55 | 12.8 | 2.21 | 2.96 | 5.17 | .747 | .428 | .573 |
| Tom Watson | 10 | 55 | 11.0 | 2.23 | 3.31 | 5.54 | .674 | .402 | .608 |
| Thurmond Grey | 10 | 55 | 10.6 | 2.42 | 3.39 | 5.81 | .714 | .416 | .581 |
| Hybrid 62 | 10 | 50 | 10.8 | 2.22 | 2.36 | 4.58 | .941 | .485 | .515 |
| Winter Queen | 10 | 55 | 9.8 | 1.28 | 2.83 | 4.11 | 0.452 | 0.312 | 0.688 |

purposely delayed until the soil temperature reaches 25° to 30° C. This practice results in prompt death of susceptible seedlings, whereas if seed is planted at soil temperatures of between 20° and 22° C, many potentially susceptible plants survive until they form runners. In such late-planted plots of Klondike R7, many self-pollinations were made, usually from July 15 to August 15. The resulting selfed fruits were left attached to the plant until they were fully ripened. Fruits selfed in late July are ripe approximately 50 days from anthesis, whereas fruits selfed in mid-August frequently require 65 to 75 days to reach maturity. On the same plant, very frequently two or even four fruits were produced; all were tested when mature for total soluble solids. Almost without exception, the fruits selfed in July were higher in total soluble solids than those selfed in August.

In 1937, to check further the variation in sugar content of the same variety when grown under different environmental conditions, Klondike R7 was planted on May 17, June 14, and July 5. These three plots were designated as *A*, *B*, and *C*, respectively, and were located in adjacent rows in the field. Cultural conditions were as nearly identical as possible. The seed represented the seventh generation of a cross of Iowa Belle × Klondike, the variety Klondike R7 being resistant to wilt. The plants of plots *A* and *B* apparently grew normally with the usual fruit set for this variety, although, as would be expected, the plants in plot *B* bloomed later than in plot *A*. Plot *C*, planted on July 5, failed to make normal vine growth although grown in fertile soil and adequately supplied with water. Fruit set was abnormally sparse, and fruits attained only about one-half normal weight for the variety. In all cases, the fruits were allowed to reach maturity on the vines, then they were cut and the total soluble solids content determined. Sugar analyses were also made except for the crop harvested on November 24. Ordinarily frost kills watermelon vines at Davis about November 1, but 1937 was abnormal in this respect. The results appear in table 13.

Considering the fruits of plot *A*, it is apparent that at the six dates of harvest the total soluble solids were remarkably uniform. The greatest variation in total sugars occurred on September 2 and September 23 when this difference was only 1.08 per cent. There is a very obvious change in the ratio between sucrose and reducing sugars; this constantly increased with each harvest. The average maximum and minimum total soluble solids content of individual fruits were 13.4 and 11.2, respectively, with 10.39 per cent average total sugar content for the six samples. Similar data might be cited for practically all of the varieties listed in table 6, indicating the same trend; that is, a very slight (probably

TABLE 13

DATE OF PLANTING AND OF FRUIT MATURITY AS AFFECTING TOTAL SOLUBLE SOLIDS AND SUGAR CONTENT OF KLONDIKE R7; 1937

| Plot and date of planting | Date of harvesting | Number of fruits | Total soluble solids, per cent | Sugars, per cent | | | Maximum and minimum per cent total soluble solids of individual fruits |
|---|---|---|---|---|---|---|---|
| | | | | Total | Reducing | Sucrose | |
| Plot A, May 17 | Sept. 2 | 10 | 12.5 | 11.02 | 7.03 | 3.99 | 13.8 and 11.2 |
| | Sept. 6 | 9 | 12.0 | 10.15 | 4.33 | 5.82 | 12.8 and 10.8 |
| | Sept. 20 | 10 | 12.0 | 10.48 | 4.08 | 6.40 | 13.0 and 11.0 |
| | Sept. 23 | 9 | 11.7 | 9.94 | 3.42 | 6.52 | 13.0 and 10.8 |
| | Sept. 30 | 10 | 12.4 | 10.23 | 2.89 | 7.34 | 14.6 and 11.4 |
| | Oct. 6 | 5 | 12.2 | 10.54 | 2.79 | 7.75 | 13.0 and 12.0 |
| *Average* | ........ | .. | *12.1* | *10.39* | *4.09* | *6.30* | *13.4 and 11.2* |
| Plot B, June 14 | Sept. 30 | 7 | 12.0 | 10.29 | 4.42 | 5.87 | 13.2 and 10.8 |
| | Oct. 7 | 9 | 11.7 | 10.48 | 4.19 | 6.29 | 13.0 and 9.8 |
| | Nov. 24 | 10 | 10.3 | ..... | .... | .... | 11.8 and 9.0 |
| *Average* | ........ | .. | *11.3* | ..... | .... | .... | *12.2 and 9.9* |
| Plot C, July 5 | Nov. 24 | 5 | 9.6 | ..... | .... | .... | 11.0 and 8.0 |

insignificant) difference in total soluble solids content from the May 17 planting.

From plot *B*, with samples harvested on September 30, October 7, and November 24, apparently significant variations are evident, particularly when comparing the September 30 with the November 24 harvest; the soluble solids decreased from 12.0 to 10.3, the maximum total soluble solids content from 13.2 to 11.8, and the minimum from 10.8 to 9.0 per cent. Furthermore, a consistent decrease in total soluble solids is evident from the September 30 through the October 7 to November 24 harvest.

As stated previously, the vines in plot *C* failed to make normal growth and the resulting fruits were distinctly undersized. Only one crop was harvested and that on November 24. Only 5 of the 7 fruits (10 vines constituted this plot) were fully ripe. These averaged 9.6 per cent total soluble solids with 11.0 and 8.0 per cent as the maximum and minimum respectively.

The data show that if Klondike R7 is planted out of season the resulting fruits may vary in total soluble solids, even though this variety may be considered genetically pure for the factor or factors governing total soluble solids content. It would thus seem particularly desirable to make total soluble solids determinations of such a pure strain in various sections of the country. It would also seem logical to further investigate this response by comparing varieties of high and low sugar content, such as striped Klondike No. 11 and Improved Stone Mountain No. 5 when both varieties are planted in May, June, and July.

The possible effects on total soluble solids and total sugars of annual environmental variables are also worthy of consideration. In table 14 are presented comparative data on seven varieties of watermelons used in these determinations in both 1935 and 1937. The seed used for each variety in the two years, however, was not always identical. Striped Klondike No. 11 and California Klondike No. 3 were constantly being inbred for uniformity and quality, with particular attention given to total sugar content. By 1937 these two varieties had been inbred for five and eleven generations respectively. Seed of Iowa Belle and Pride of Muscatine was secured from the Iowa Agricultural Experiment Station where they had been constantly inbred for quality. Seed of the three remaining varieties was secured from five seed companies and well mixed before planting to secure a composite sample. This was intentional, so there would be an acceptable average collection for these three important commercial varieties. Similar comparisons for other varieties in other years might be included, but it seems unnecessary as the comparisons closely agree with those in table 14.

The varieties for each year are tabulated in order of decrease in sugar content. In both years, Striped Klondike No. 11 and California Klondike No. 3 occupied first and second positions respectively. There was only slight variation in the total sugar content for each variety during the two years. Stone Mountain and Iowa Belle exchanged positions. Tom Watson was in fifth position each year, while Pride of Muscatine and

TABLE 14

COMPARATIVE TOTAL SOLUBLE SOLIDS AND SUGARS OF SEVEN WATERMELON VARIETIES IN 1935 AND 1937

| Variety | Total soluble solids, per cent | Sugars, per cent | | | Ratio of total sugars to total soluble solids |
|---|---|---|---|---|---|
| | | Total | Reducing | Sucrose | |
| Determinations for 1935 | | | | | |
| Striped Klondike No. 11 | 12.4 | 10.50 | 5.82 | 4.68 | 0.847 |
| California Klondike No. 3 | 11.6 | 10.07 | 5.80 | 4.27 | .868 |
| Stone Mountain | 11.0 | 9.46 | 5.82 | 3.64 | .860 |
| Iowa Belle | 10.9 | 9.42 | 5.50 | 3.92 | .864 |
| Tom Watson | 10.4 | 8.45 | 5.49 | 2.96 | .813 |
| Thurmond Grey | 10.2 | 8.55 | 5.60 | 2.95 | .838 |
| Pride of Muscatine | 9.9 | 8.71 | 6.58 | 2.13 | 0.880 |
| *Average* | *10.9* | *9.31* | *5.80* | *3.51* | *0.854* |
| Determinations for 1937 | | | | | |
| Striped Klondike No. 11 | 12.6 | 10.77 | 3.93 | 6.84 | 0.855 |
| California Klondike No. 3 | 12.1 | 10.47 | 3.50 | 6.97 | .865 |
| Iowa Belle | 11.4 | 10.03 | 4.22 | 5.81 | .880 |
| Stone Mountain | 11.0 | 9.64 | 4.74 | 4.90 | .877 |
| Tom Watson | 10.9 | 9.34 | 3.82 | 5.52 | .857 |
| Pride of Muscatine | 10.2 | 9.04 | 5.84 | 3.20 | .886 |
| Thurmond Grey | 10.2 | 8.65 | 3.80 | 4.85 | 0.848 |
| *Average* | *11.2* | *9.71* | *4.27* | *5.44* | *0.867* |

Thurmond Grey exchanged positions. Pride of Muscatine was probably more stable, genetically, in 1937 than in 1935, and the same holds for Iowa Belle. It is apparent that the total sugar content in 1937 was only slightly higher than in 1935. The total sugar in Stone Mountain increased from 9.46 to 9.64, in Thurmond Grey from 8.55 to 8.65, and in Tom Watson from 8.45 to 9.34 per cent. The seed used for both tests was identical, genetically; the actual average difference in both total soluble solids and total sugars was only 0.3 and 0.4 per cent, respectively. These differences were doubtless due to variations in environmental conditions; the order remained practically identical for the two years, indicating that although environmental conditions did affect both total soluble solids and total sugars, the seven varieties were similarly affected.

## SUMMARY

High quality in watermelons is largely dependent upon high total sugar content. Other factors determining high quality are deep-red color and pleasant texture of the edible flesh.

The various Klondike types of watermelons, during the five years of observation at Davis, have consistently shown higher sugar content than the more important varieties extensively grown in the states east of the Rocky Mountains. Incidentally, the Klondike types grown in California excel these eastern varieties in flesh texture; differences in flesh color are less pronounced. These varieties have been named California Klondike Nos. 1, 3, and 8, Striped Klondike No. 11, Klondike R16 (not released to date), and Klondike R7.

Of the many wilt-resistant varieties, Klondike R16 and Klondike R7 excel the others in sugar content. Improved Kleckley Sweet No. 6 follows closely. Leesburg contains approximately the same amount of total sugar as Thurmond Grey, and Hawkesbury the same as Tom Watson.

When grown at Davis, the important wilt-susceptible varieties may be arranged, in order of decreasing sugar content, as follows: Striped Klondike No. 11, commercial Klondike, California Klondike No. 3, Dixie Queen, Stone Mountain, Tom Watson, Kleckley Sweet, Thurmond Grey, and Northern Sweet.

The trends for total soluble solids and total sugars are essentially alike, and approximately 85 per cent of the total soluble solids is sugar; therefore, it seems justifiable to use the hand refractometer in determining relative sweetness of juices of watermelons.

Experimental data show that two or three drops of juice taken from the center of one-half of a fully mature fruit give approximately the same refractometric reading as a composite sample taken from the entire edible tissue located almost entirely within the seed zone of the same half.

Juice taken from the edible tissues near the stem end of the fruit usually contains less sugar than samples taken from the tissues near the blossom end.

The formation of reducing sugars in fruits of commercial Klondike and related varieties begins sometime previous to the tenth day from anthesis. Sucrose is seldom detected before the twentieth day, when a rather small amount is found. Thereafter, sucrose formation proceeds rapidly until in mature fruits (45 days for Klondike at Davis) approximately 35 per cent of the total sugar is sucrose.

In overmature fruits attached to the vines as well as in mature fruits stored at room temperature for two weeks or more, there is a rapid

increase in the ratio between sucrose and reducing sugars. Frequently, in such fruits sucrose represents 65 per cent of the total sugar.

There is a slight loss of total sugars, usually less than 1 per cent, in stored fruits; the amount depends upon the degree of maturity at harvest time, upon the length of storage period, and very probably upon temperature and humidity.

It is evident that reducing sugars are formed first and that with approaching maturity sucrose development proceeds rapidly. Thereafter, the ratio of sucrose to reducing sugars is gradually reversed, sucrose predominating either in overmature or in mature stored fruits.

Of the reducing sugars, levulose predominated over dextrose in limited tests. The dextrose-levulose ratio steadily increases as the fruits develop, indicating that dextrose increases more rapidly than levulose.

Variation in total soluble solids and total sugar due to varying environmental influences is briefly discussed although the results to date are not considered conclusive.

The desirability is indicated of inbreeding to eliminate low-sugar individuals and to stabilize the remainder. These results fortify previous investigations on the effects of inbreeding.

Varieties of relatively low total soluble solids and total sugar content contain individual plants which produce high-sugar fruits. Controlled pollination and careful selection should tend to increase the average total soluble solids and total sugar content. It would seem logical to undertake systematic cross-breeding using a known high-sugar strain as one parent.

## LITERATURE CITED

1. Association of Official Agricultural Chemists.
1930. Official and tentative methods of analysis. 3rd ed. Association of Official Agricultural Chemists, Washington, D. C.

2. Browne, C. A.
1912. A handbook of sugar analysis. 787 p. John Wiley and Sons, New York, N. Y.

3. Lothrop, R. E., and R. L. Holmes.
1931. Determination of dextrose and levulose in honey by use of iodine-oxidation method. Indus. and Engin. Chem., anal. ed. 3(3):334–39.

4. Porter, D. R.
1933. Watermelon breeding. Hilgardia 7(15):585–624.

5. Porter, D. R.
1937. Inheritance of certain fruit and seed characters in watermelons. Hilgardia 10(12):488–509.

6. Porter, D. R.
1937. Breeding high-quality wilt-resistant watermelons. California Agr. Exp. Sta. Bul. **614**:1–43.

7. Porter, D. R., and C. S. Bisson.
1934. Total soluble solids and sugars in watermelons. Amer. Soc. Hort. Sci. Proc. 32:596–99.

8. Porter, D. R., and I. E. Melhus.
1932. The pathogenicity of *Fusarium niveum* (EFS) and the development of wilt-resistant strains *Citrullus vulgaris* (Schrad.). Iowa Agr. Exp. Sta. Research Bul. **149**:123–84.

9. Tucker, L. R.
1934. Soluble solids in the watermelon. Plant Physiol. 9:181–82.

10. Walker, M. N.
1936. A new wilt-resistant watermelon for Florida. Florida Agr. Exp. Sta. Bul. 288:3–13.

11. Wenholz, H.
1936. Plant breeding in New South Wales. Ninth year of progress, 1934–35. N. S. Wales Dept. Agr. Sci. Bul 51:42.

# VARIATION IN SOLIDS OF THE JUICE FROM DIFFERENT REGIONS IN MELON FRUITS

G. W. SCOTT AND JOHN H. MacGILLIVRAY

# VARIATION IN SOLIDS OF THE JUICE FROM DIFFERENT REGIONS IN MELON FRUITS[1]

G. W. SCOTT[2] AND JOHN H. MACGILLIVRAY[3]

THE IMPORTANCE of quality in melons (*Cucumis melo* L.) has prompted research to compare existing varieties in attempts to improve their flavor and palatability through selection and breeding; and incidental to this is the need for a basis upon which to formulate a state standard to regulate or prevent the shipment of melons low in soluble solids. These considerations make it desirable to have adequate methods for obtaining and analyzing samples, and to have a clear conception of the possible variability in different regions of the cantaloupe fruit. This paper presents data on the variability of solids in melons and discusses methods of testing and sampling.

Palatability of melons has usually been associated with sugar content and other water-soluble solids. The soluble solids consist largely of sugars together with minor amounts of dissolved compounds of nitrogen, minerals, and other constituents. It is generally accepted that there is a correlation between sugar content and palatability or quality of melons (*3*)[4]; this seems true even though the flavor factor has not been measured. As a cantaloupe ripens there is an increase in total solids, and a decrease in reducing sugars, as well as a softening of the flesh and a development of color (*9*).

## REVIEW OF LITERATURE

Chace, Church, and Denny (*3*) were among the first to make use of the immersion refractometer in determining the relative concentrations of cantaloupe juice. Their samples consisted of the juice from the entire edible flesh and they were able to show a positive correlation between the density of the juice, or percentage of sucrose, and the eating quality of melons. The density of the juice was determined at different stages of maturity. A few years later Rosa (*9*) reported a study upon the effect of stage of maturity on the composition of melons. Longitudinal segments were preserved in alcohol for chemical analysis. Juice was also

[1] Received for publication December 20, 1938.

[2] Research Assistant in the Experiment Station; resigned June 6, 1936.

[3] Assistant Professor of Truck Crops and Associate Olericulturist in the Experiment Station.

[4] Italic numbers in parentheses refer to "Literature Cited," at the end of this paper.

expressed and the density determined by means of a Brix spindle. Rosa expressed the relation between the solids soluble in 55 per cent alcohol and the total solids. The alcohol-soluble solids may differ in amount from the water-soluble solids. He found that 94 per cent of the total solids were soluble in the case of Golden Beauty Casabas, 87 per cent in Honeydews, and 93 per cent in black-seeded Angeleno watermelons.

Tucker (*13*), although his data were limited to one fruit, has pointed out the variations in the soluble-solids content in different regions of the watermelon. There was also some indication that the stem end was lower in hand-refractometer reading (soluble solids) than the blossom end. Lloyd[5] observed that there was considerable difference in the quality of different parts of the same cantaloupe. The stem end and the undersides of the fruits were usually of poorer quality than the blossom end and the top. The underside of a melon, especially at the point of contact with the ground, was usually of poorer quality than the upper portion of the same melon. All quality tests were made by tasting and extended through two seasons. Scott (*11*) published an abstract of the results obtained with *Cucumis melo* L. in 1935 and these data are included in this paper.

## METHODS AND RESULTS

There are several methods available for determining the concentration of solids in the juice of melons. Various workers have used the Brix hydrometer or spindle, and the Abbé, immersion, and hand refractometers. Since there are three different scales represented by these instruments, it seems desirable to explain the relation between them. The scale readings of each of these instruments give an indication of the relative concentrations of similar solutions when tested. The Brix hydrometer scale is calibrated by means of solutions of pure sucrose in water and the scale is expressed in per cent sucrose. Juice from mature cantaloupes contains over 50 per cent sucrose and the Brix hydrometer has therefore been used to indicate the per cent soluble solids, although obviously the results are not so accurate as with pure sucrose solutions. The scale readings of refractometers are based on the refractive index of the liquid being tested; in some instruments the scale reading is established arbitrarily, while in others (Abbé) the scale readings indicate directly the refractive index. The arbitrary scale reading of the immersion refractometer may be expressed in terms of refractive indices by calibration. From a table of refractive indices of sucrose-water solutions the percentage composition of an unknown sucrose-water solution may

[5] Lloyd, J. W. Studies of variation in the quality of melons. p. 213–14. Unpublished thesis, filed in Cornell University Library, Ithaca, New York.

therefore be obtained. The hand refractometer has been in use for only a few years. The manufacturer has expressed the scale in percentage of "dry substance" and has indicated that the scale was determined about the year 1910 by means of pure sucrose solutions. Thus, the scale readings express the percentage of both the soluble solids and total solids for standard sucrose solutions, while if plant juices containing other dissolved substances are tested, the scale readings give only approximate percentages of soluble solids. In the early work with cantaloupes, the Brix reading was referred to as the "soluble solids" (*3*). In more recent

TABLE 1

THE RELATION BETWEEN THE REFRACTIVE INDEX AND THE PER CENT SOLUBLE SOLIDS OF SUGARS AND OTHER SOLUTIONS*

| Refractive index, 20° C | Sucrose | Maltose | Commercial glucose | Lactose | Dextrin | Soluble solids in tomato pulp |
|---|---|---|---|---|---|---|
| 1.3402 | 5.00 | 5.07 | 5.00 | 5.13 | 4.87 | 4.60 |
| 1.3477 | 10.00 | 10.07 | 10.07 | 10.13 | 9.60 | 9.45 |
| 1.3555 | 15.00 | 15.12 | 15.06 | 15.13 | 14.13 | .... |
| 1.3637 | 20.00 | 20.17 | 20.06 | ..... | 18.94 | .... |

* Data in columns for sucrose, maltose, commercial glucose, lactose, and dextrin are from table XV of bibliography citation *2*; data for the column of soluble solids in tomato pulp, are from citation *1*.

work with watermelons the hand-refractometer reading has also been referred to either as "soluble solids" or "total soluble solids" (*6, 7, 8*). The California Standardization Act is enforced for cantaloupes on the basis of minimum per cent of soluble solids in the edible portion, and consequently this term is in common use by growers and shippers.

The Brix spindle and hand refractometer indicate the relative concentration of melon juice on the basis of comparative sucrose solutions. It seems possible that the fruit juices containing other soluble material than sucrose may be subject to a corrective factor before readings will accurately express soluble solids. Browne (*2*) and Bigelow and Fitzgerald (*1*) have made such comparisons between refractive index and soluble solids. Some of these data are found in table 1. There are still wider variations where the solids of inorganic salts are compared as to their refractive index and soluble solids. A silver nitrate solution (*4*) with a refractive index of 1.33484 at 20° C contains 1.7 per cent solids. An ammonium sulfocyanate solution with a refractive index of 1.33499 at 20° C contains 0.8 per cent solids. Both of these solutions are tenth molar. With these facts in mind, it seemed desirable to give the data as hand-refractometer readings in the tables, and to use the term "soluble solids" in the text, because of its common use in the melon industry.

*Method of Sampling Fruits.*—The melons were cut into cross and longitudinal sections to determine their possible variability. These procedures are described in succeeding paragraphs, and are illustrated by figures 1, 2, and 3. The edible flesh was removed from the rind, cut into small pieces, and the juice from the whole section was obtained by press-

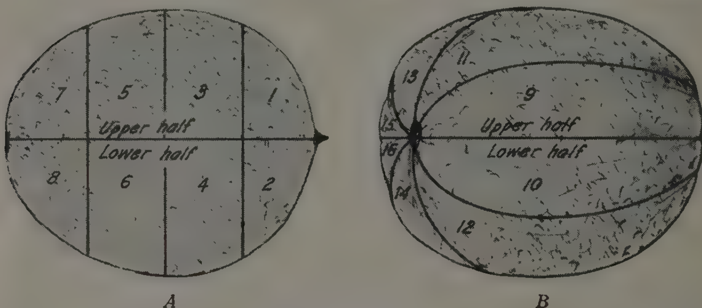


Fig. 1.—The melons used for data presented in table 2 were first cut along their polar diameters through the stem and blossom ends parallel to the ground. In *A*, subsequent vertical cuts were made so that there were 8 equal sections. In *B*, 8 longitudinal sections were cut.

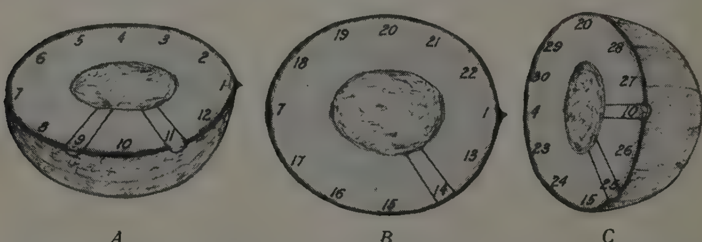


Fig. 2.—Location of taking sample cores for data found in table 3: *A*, a longitudinal section cut parallel to the ground; *B*, a longitudinal section cut vertical to the ground; and *C*, a cross section made midway between the stem and blossom ends. Cores were taken at all locations indicated by the numbers except in the case of cantaloupe where the samples were taken only from locations shown in *A* and *C*.

ing it through fine cheesecloth. The hand or field refractometer was adjusted for laboratory temperatures.

In the twenty fruits for the data in table 2 (fig. 1) the first cut was made through their blossom and stem ends parallel to the ground. In ten of these, subsequent vertical cuts were made so that there were 8 equal halves of cross sections (fig. 1, *A*), while the other ten fruits were cut along the sutures of their polar (*10*) diameters to obtain 8 equal longitudinal sections (fig. 1, *B*). The samples for the determinations

presented in table 3 were obtained by means of a cork borer from a single fruit each of cantaloupe and Honeydew; the cores were 9/16 inch in diameter and were taken at the locations indicated in figure 2.

The melons for the data in table 4 (fig. 3) were first cut through their blossom and stem ends (and ground spot), vertical to the ground (fig. 3, *A* and *B*). One half (fig. 3, *A*) was cut into longitudinal sections as shown in figure 1, *B*. One longitudinal section was cut from the other half

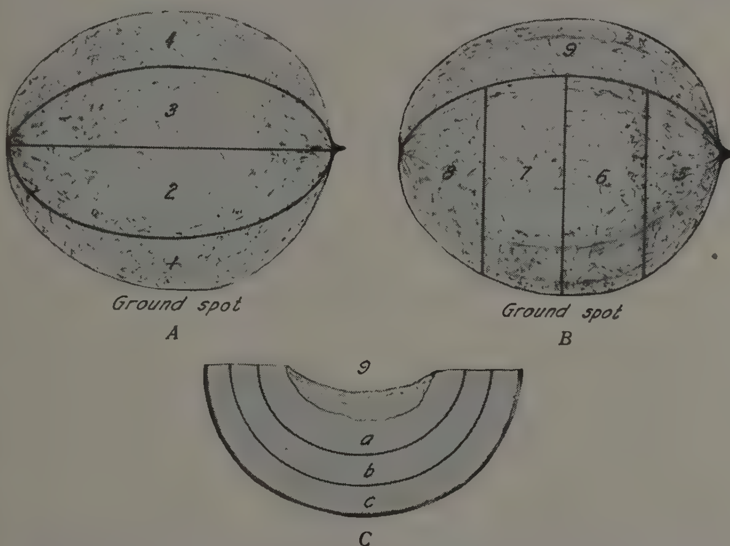


Fig. 3.—For data presented in table 4, each melon was cut in half along the polar diameter, vertical to the ground, the cut passing through the middle of the ground spot. *A*, longitudinal sections from half the melon; *B*, the other half of the melon from which one longitudinal section was cut, and four cross sections; and *C*, the last longitudinal section separated into three sections from the seed cavity to the rind.

for section 9, and the remainder was cut into cross sections as shown in figure 3, *B*. Determinations were made on regions 9*a*, *b*, and *c*, as shown in figure 3, *C*. In tables 2 and 4, the juice was obtained from large sections, and consequently was a composite sample for the section. Samples obtained by means of the cork borer were from a much smaller area than the other samples.

In 1935 and 1937, there was little difference between the soluble-solids (refractometer reading or dry substance) content of the different longitudinal sections. None of the sections were consistently lower or higher in soluble solids, and in 60 per cent of the comparisons the differ-

TABLE 2

HAND-REFRACTOMETER READINGS (PER CENT SOLUBLE SOLIDS) FROM DIFFERENT REGIONS OF THE EDIBLE PORTION OF MELONS; 1935

| Regions of fruit sampled | Sample section (fig. 1) | Upper half | | | | Sample section (fig. 1) | Lower half | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cantaloupe | Honeydew | Casaba | Average | | Cantaloupe | Honeydew | Casaba | Average |
| Cross sections of 10 fruits | | | | | | | | | | |
| Stem end | 1 | 8.6 | 9.6 | 8.7 | 8.9 | 2 | 9.6 | 10.0 | 9.3 | 9.6 |
| Middle (stem end) | 3 | 10.9 | 10.5 | 9.9 | 10.4 | 4 | 10.7 | 11.2 | 10.2 | 10.7 |
| Middle (blossom end) | 5 | 11.1 | 10.9 | 10.1 | 10.7 | 6 | 10.7 | 11.2 | 10.3 | 10.7 |
| Blossom end | 7 | 10.4 | 10.7 | 10.0 | 10.4 | 8 | 10.4 | 10.6 | 9.9 | 10.3 |
| Longitudinal sections of 10 fruits | | | | | | | | | | |
| First segment | 9 | 9.4 | 10.9 | 9.5 | 9.9 | 10 | 9.1 | 10.8 | 9.4 | 9.8 |
| Second segment | 11 | 9.6 | 10.9 | 9.6 | 10.0 | 12 | 8.9 | 10.4 | 9.4 | 9.6 |
| Third segment | 13 | 9.5 | 10.8 | 9.7 | 10.0 | 14 | 8.9 | 10.6 | 9.0 | 9.5 |
| Fourth segment | 15 | 9.2 | 10.8 | 9.7 | 9.9 | 16 | 9.0 | 10.3 | 9.4 | 9.5 |
| Coefficient of variability of cross sections* | .. | 12.5 | 17.4 | 15.1 | .... | .. | 13.5 | 15.3 | 16.7 | .... |
| Coefficient of variability of longitudinal sections* | .. | 7.3 | 11.4 | 11.1 | .... | .. | 8.1 | 16.2 | 13.6 | .... |

* The standard error of the coefficient of variability was calculated according to the following formula (see bibliography citation *12*): $\frac{v}{\sqrt{2n}}\sqrt{1+2\left(\frac{v}{100}\right)^2}$. The standard error of the difference between the coefficients of variability was determined and the difference considered significant when greater than twice the standard error. All differences between coefficients of variability of cross and longitudinal sections of the same variety and melon half are significant.

ence was equal to the accuracy of the hand refractometer. The data in table 3, as well as the cross-section results indicate that different areas in these longitudinal sections are variable in soluble solids. As the juice was taken from the entire segment, these differences were neutralized.

The stem end quarter of the cross sections (tables 2 and 4) was always lowest in soluble solids, with either the middle blossom quarter or the blossom quarter highest in percentage of soluble solids. When the sample was obtained by means of a small plug at the blossom end (table 3), this area was definitely highest in soluble solids. The longitudinal sections show less variability between the different sections than do the four cross sections.

*Regions of Flesh.*—In eating cantaloupes it has been a common observation that the inner flesh next to the cavity was more desirable than the flesh next to the rind. It seemed desirable to measure the variability of these regions. In 1937 a longitudinal section was obtained from each melon and divided into (1) one-third of the inner flesh next to the placental cavity, (2) the next third of the flesh which was firmer in consistency, and (3) the last third which was next to, but did not include, the rind (table 4, figure 3, *C*).

The inner flesh was always greatest in soluble solids, and there was a consistent decrease as the samples were obtained closer to the rind. In taking samples of a portion of the fruit or the whole fruit great care should be used to sample a uniform distance from the rind.

*Placenta.*—This region although never eaten is the first portion of the fruit to disintegrate upon ripening. A full-slip melon contains a large number of fibrous strands and seeds imbedded in gelatinous material. Readings were made on the region in order that there would be a complete analysis of the different regions of the fruit.

The placenta, blossom quarter, and inner flesh of the longitudinal section, are all high in percentage of soluble solids. The placental tissue was higher in percentage of soluble solids than the blossom-end quarter in five out of eight determinations, found in table 4. In some preliminary results where the sections were fewer and larger, the placental tissue was always highest in soluble solids. In all cases the regions of high soluble solids were associated with greater ripeness and softness of the flesh.

*Storage.*—Duplicate melons were stored at room temperature for about 6½ days, in 1937 (table 4), and the soluble solids were determined from the different regions. Fruits tested immediately and those stored were as nearly identical as was possible to obtain. After storage the cantaloupes were lower in soluble solids, the Persian melons changed slightly, while the Honeydews were slightly higher in solids. Storage did

TABLE 3

HAND-REFRACTOMETER READINGS (PER CENT SOLUBLE SOLIDS) FROM CORES OF DIFFERENT REGIONS OF THE EDIBLE PORTION OF ONE FRUIT EACH OF CANTALOUPE AND HONEYDEW; 1935

| Cantaloupe | | | | Honeydew | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Longitudinal section parallel to ground | | Cross section at equatorial diameter | | Longitudinal section parallel to ground | | Longitudinal section at a right angle to ground | | Cross section at equatorial diameter | |
| Sample no. (fig. 2, *A*) | Reading | Sample no. (fig. 2, *C*) | Reading | Sample no. (fig. 2, *A*) | Reading | Sample no. (fig. 2, *B*) | Reading | Sample no. (fig. 2, *C*) | Reading |
| 1 | 9.8 | 4 | 11.6 | 1 | 13.0 | 1 | 13.0 | 4 | 14.8 |
| 2 | 10.8 | 23 | 11.8 | 2 | 15.0 | 13 | 13.4 | 23 | 14.2 |
| 3 | 11.2 | 24 | 11.4 | 3 | 14.4 | 14 | 14.2 | 24 | 14.0 |
| 4 | 11.6 | 15 | 11.6 | 4 | 15.0 | 15 | 14.6 | 15 | 14.6 |
| 5 | 12.0 | 25 | 11.6 | 5 | 15.4 | 16 | 15.0 | 25 | 14.4 |
| 6 | 12.8 | 26 | 11.4 | 6 | 15.6 | 17 | 15.0 | 26 | 14.4 |
| 7 | 13.0 | 10 | 11.6 | 7 | 16.0 | 7 | 16.0 | 10 | 14.4 |
| 8 | 12.4 | 27 | 11.6 | 8 | 15.4 | 18 | 15.4 | 27 | 13.0 |
| 9 | 11.4 | 28 | 12.2 | 9 | 15.4 | 19 | 14.2 | 28 | 13.8 |
| 10 | 11.6 | 20 | 12.2 | 10 | 14.8 | 20 | 14.2 | 20 | 14.2 |
| 11 | 10.8 | 29 | 12.0 | 11 | 14.2 | 21 | 13.4 | 29 | 14.8 |
| 12 | 10.2 | 30 | 11.4 | 12 | 14.6 | 22 | 13.6 | 30 | 15.4 |

TABLE 4

HAND-REFRACTOMETER READINGS (PER CENT SOLUBLE SOLIDS) FROM DIFFERENT REGIONS OF THE EDIBLE PORTION OF FRESH AND STORED MELON FRUITS, 1937

| Fruit sample | Sample section (fig. 3) | Fresh | | | | Stored for 6½ days | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cantaloupe full slip | Cantaloupe, half slip | Honeydew | Persian | Cantaloupe, full slip | Cantaloupe, half slip | Honeydew | Persian |
| Placenta | .. | 13.0 | 10.2 | 11.8 | 10.9 | 12.0 | 10.2 | 12.9 | 11.1 |
| Longitudinal sections of 10 halves | | | | | | | | | |
| Ground spot | 1 | 12.2 | 10.3 | 11.7 | 10.6 | 11.2 | 10.0 | 12.0 | 10.5 |
| Next to ground spot | 2 | 12.2 | 10.3 | 11.8 | 10.5 | 11.2 | 10.1 | 12.0 | 10.6 |
| Next to top | 3 | 12.0 | 10.1 | 11.6 | 10.4 | 11.2 | 10.1 | 12.1 | 10.7 |
| Top | 4 | 12.2 | 10.3 | 11.5 | 10.1 | 11.2 | 10.0 | 12.0 | 10.5 |
| Cross sections of 10 three-eighths melon | | | | | | | | | |
| Stem quarter | 5 | 11.1 | 9.4 | 10.3 | 9.5 | 10.1 | 9.3 | 10.6 | 9.4 |
| Middle stem quarter | 6 | 11.9 | 10.4 | 11.5 | 10.2 | 11.0 | 9.8 | 12.0 | 10.3 |
| Middle blossom quarter | 7 | 12.6 | 10.6 | 12.2 | 10.5 | 11.8 | 10.0 | 12.5 | 10.6 |
| Blossom quarter | 8 | 12.8 | 10.6 | 12.2 | 10.3 | 11.9 | 10.5 | 12.5 | 10.4 |
| Longitudinal section | | | | | | | | | |
| Inner flesh | 9a | 13.1 | 10.9 | 12.8 | 11.0 | 12.1 | 10.6 | 13.1 | 11.2 |
| Middle flesh | 9b | 11.5 | 9.3 | 10.4 | 9.4 | 10.7 | 9.5 | 10.8 | 9.1 |
| Rind flesh | 9c | 9.5 | 7.3 | 7.7 | 7.4 | 9.8 | 8.5 | 8.3 | 6.8 |
| Coefficient of variability* of longitudinal sections (1–4) | .. | 5.3 | 14.0 | 16.6 | 15.5 | 14.2 | 19.9 | 14.5 | 14.9† |
| Coefficient of variability* of cross sections (5–8) | .. | 8.8 | 15.6 | 19.4 | 17.2 | 16.0 | 16.2 | 16.4 | 15.5† |
| Coefficient of variability*‡ of longitudinal sections (9, *a*, *b*, *c*) | .. | 15.9 | 21.4 | 27.6 | 21.6 | 21.0 | 22.2 | 23.3 | 25.9 |

* The standard error of the coefficient of variability was calculated by the following formula (see bibliography citation *12*): $\frac{v}{\sqrt{2n}}\sqrt{1+2\left(\frac{v}{100}\right)^2}$. The standard error of the difference between the coefficients of variability was determined, and the difference considered significant when greater than twice the standard error.

† All comparisons between longitudinal and cross sections are significant except in the case of the Persian variety.

‡ The samples from the longitudinal sections (9*a*, *b*, *c*) are significantly more variable than the cross sections (5-8).

not make an appreciable change in the relative variability of the cross and longitudinal sections.

*Statistical Analysis.*—A comparison of the coefficients of variability of the longitudinal and cross sections indicate that the longitudinal sections are the least variable. In both tables 2 and 4 there is one case each where the longitudinal sections are the most variable, and the difference between the methods of sampling is not significant for the stored Persian melons. The three regions of the longitudinal section marked as 9*a*, *b*, and *c* are more variable than either the cross sections (5–8) or the longitudinal sections (1–4). It is evident that sampling by longitudinal sections is the most desirable.

In order to determine whether there was any significant difference between the longitudinal sections, they were compared in the following manner by the use of "Student's" method (*5*). The *Z* value was obtained by comparing each longitudinal section with every other longitudinal section. In 76 out of the possible 84 comparisons, it made no difference as to which one of the longitudinal sections was used. In the comparisons between the longitudinal sections of the lower half of Honeydews, there were found three comparisons where the differences were significant; in the fresh Honeydews there were two comparisons that were significant. The statistical data seem to support an observational analysis of the data when recognition is taken of the fact that melons are variable in composition, there is no exact method of removing the same proportional amount of flesh from each section, and the small number of fruits used.

## SUMMARY

It is evident from these data that the different regions in the individual fruits of *Cucumis melo* L. are variable in composition and extreme care should be taken when either the entire edible flesh or any section of the melon is used for a composite sample.

The results indicate that the two most satisfactory methods of obtaining samples for soluble solids are as follows: (1) Pressing the juice from all of the edible flesh, using care to remove a uniform percentage of the flesh; and (2) pressing juice from a longitudinal segment and using care to remove a uniform percentage of the flesh.

The composition of melons is slightly changed by storage for 6½ days.

## LITERATURE CITED


1. BIGELOW, W. D., and F. F. FITZGERALD.
   1915. Examination of tomato pulp. Jour. Indus. and Engin. Chem. 7:602–6.

2. BROWNE, C. A.
   1912. A handbook of sugar analysis. 787 p. (See specifically p. 63.) John Wiley and Sons, New York, N. Y.

3. CHACE, E. M., C. G. CHURCH, and F. E. DENNY.
   1924. Relation between the composition of California cantaloupes and their commercial maturity. U. S. Dept. Agr. Bul. **1250**:1–26.

4. LEACH, ALBERT E., and ANDREW L. WINTON.
   1920. Food inspection and analysis. 1090 p. (See specifically p. 106.) John Wiley and Sons, New York, N. Y.

5. LOVE, H. H.
   1924. A modification of Student's table for use in interpreting experimental results. Jour. Amer. Soc. Agron. **16**:68–73.

6. PORTER, D. R.
   1937. Breeeding high-quality wilt-resistant watermelons. California Agr. Exp. Sta. Bul. **614**:1–43.

7. PORTER, D. R., and C. S. BISSON.
   1934. Total soluble solids and sugars in watermelons. Amer. Soc. Hort. Sci. Proc. **32**:596–99.

8. PORTER, D. R., C. S. BISSON, and H. W. ALLINGER.
   1940. Total soluble solids, reducing sugars, and sucrose in watermelons. Hilgardia **13**(2):31–66.

9. ROSA, J. T.
   1928. Changes in composition during ripening and storage of melons. Hilgardia **3**(15):421–43.

10. ROSA, J. T.
    1928. Results of inbreeding melons. Amer. Soc. Hort. Sci. Proc. **24**:79–84.

11. SCOTT, G. W.
    1936. Variation in soluble solids within individual fruits of the cantaloupe and related melons. Amer. Soc. Hort. Sci. Proc. **33**:523.

12. SINNOTT, EDMUND W., and L. C. DUNN.
    1932. Principles of genetics. 441 p. (See specifically p. 377.) McGraw-Hill Book Company, Inc. New York, N. Y.

13. TUCKER, L. R.
    1934. Soluble solids in watermelons. Plant Physiol. **9**:191–2.